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A SUMMARY OF THE SOLAR OBSERVATIONS MADE IN 1896 AT THE ASTROPHYSICAL OBSERVATORY OF CATANIA.

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THE numerical results expressed by the following tables have been deduced from solar observations which I made in 1896. The daily statistics of Sun-spots, faculæ and prominences are given in Table I; their distribution with reference to hemisphere and latitude is given in Table II; their mean frequencies are shown in Table III. The instruments and methods used were the same as in former years.

The Sun-spots were observed during 310 days, and in this period there were eight days on which the Sun appeared without a single group of spots or pores. Their mean monthly frequency has had no regularity of occurrence; it shows the most pronounced minimum in the month of May. The same irregularity may be observed in the quarter-annual means. A comparison of these results with those of the preceding year reveals an activity inferior to that of the year 1895. The highest latitudes were reached by two small groups of pores, the one in the northern hemisphere at 22°.2 on June 21, the other in the southern hemisphere at 31°.6 on January 30 and 31. The groups of spots and pores appeared at the ordinary secondary

minimum, near the equator, with a maximum in each hemisphere between 10° and 20° heliocentric latitude. Their activity, which in the preceding year had been nearly equal in the two hemispheres, was in 1896 decidedly greater in the southern hemisphere.

The faculæ were observed on 186 days; they were never absent from the visible disk of the Sun, on each of the two hemispheres. The mean frequency for different months of the year reached its greatest value in the month of December, while the most strongly marked secondary minimum was in September. On reference to the quarter-annual means it will be seen that the mean frequency of the faculæ was decreasing in the first three quarters, and that it increased in the fourth, while for the separate hemispheres, it will be found that in the northern hemisphere the faculæ had a tendency continually to increase, while in the other hemisphere there was a decrease in the first, second, and third quarters. In general, the mean frequency of the faculæ in 1896 was greater in the northern than in the southern hemisphere, and nearly equal for each hemisphere to that of 1895, with a very slight decrease.

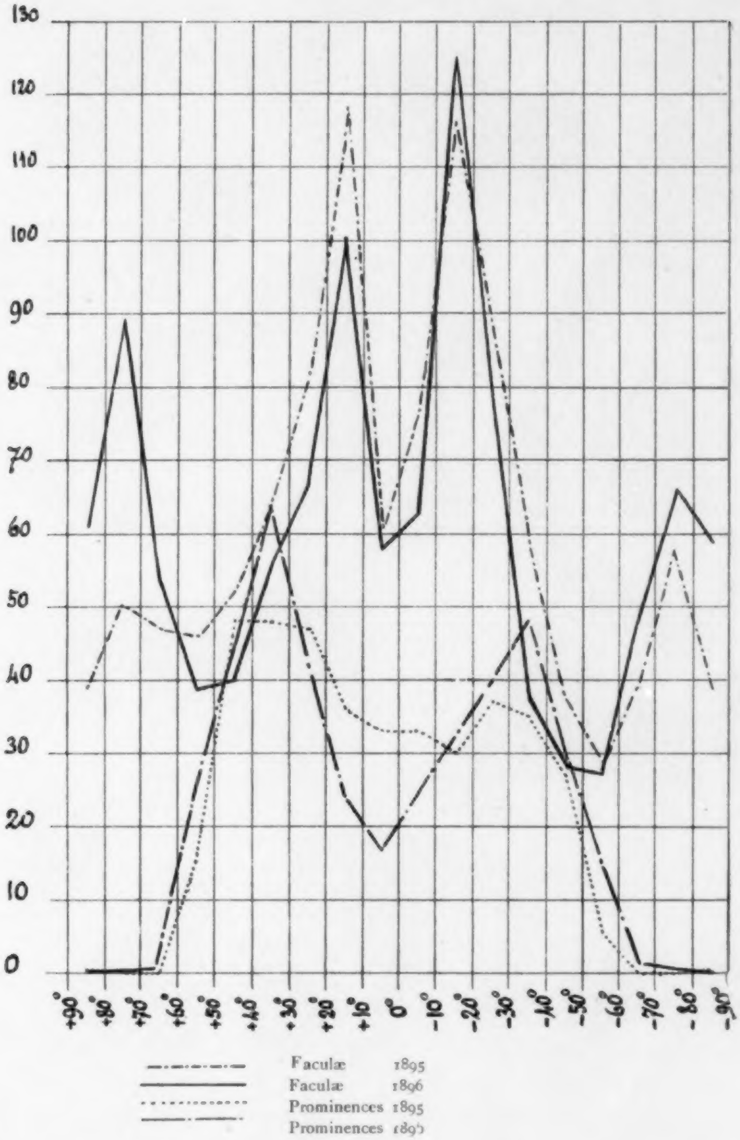
The distribution of the faculæ in zones of 10°, beginning at the equator, shows in each hemisphere two maxima symmetrically situated with respect to the equator, the principal one between 10° and 20° heliocentric latitude and the other, a secondary, between 70° and 80° latitude.

Again the faculæ present a secondary minimum at the equator and at the poles, and another larger one in the two hemispheres in the same zone ± 50° to ± 60°, that is to say, the conditions were nearly the same as in 1895.

The principal maximum of the faculæ falls in the same zone with the maximum of groups of spots and pores, just as in the preceding year 1895, but there is no correspondence of the spots with the secondary polar maxima of faculæ.

The complete spectroscopic observations of the solar limb which I was able to make in 1895, and which have been used, were 232 in number, and gave the following results: greater

PLATE XXII.



RELATIVE FREQUENCY AND DISTRIBUTION IN LATITUDE OF FACULÆ AND PROMINENCES OBSERVED AT CANTANIA IN 1895 AND 1896.

abundance of protuberances in the northern hemisphere; number of days on which the Sun was without protuberances 9; a greater abundance in the third quarter and an increase in the mean frequency for the year 1896 compared with that for 1895 —an increase which I think is merely accidental, because there is, on the contrary, a diminution in the extent of the protuberances and in their mean elevation. The distribution of the protuberances in zones of 10° shows for the two hemispheres and for the entire year, a progressive increase in the number measured as one passes from the equator to higher latitudes, up to the zone of $\pm 30° \pm 40°$, after which there is a rapid decrease, with an absolute absence near the poles. This shows us that the zones for the maximum protuberances were different from those for the spots and faculæ, and Table III again shows that corresponding to the quarter of the year of greatest activity of the protuberances there was a maximum for the faculæ, while for both phenomena the activity was greater in the northern hemisphere—that is to say, the opposite of that which occurred with respect to the spots. With reference to the discussions engaged in by Mr. Hale and M. Deslandres on the identity of the faculæ and protuberances, I have called attention in the published summaries of my solar observations made in 1894 and 1895[1] to the discordance which exists between the distributions in latitude of the faculæ and the prominences; the observations of 1896 are also in agreement with these results.

In the accompanying figure (Plate XXII) I have illustrated the march of the two phenomena, faculæ and protuberances, in the years 1895 and 1896; the abscissæ with a + sign represent north heliocentric latitudes, while the others with the − sign represent south latitudes. The ordinates represent the mean daily frequency (expressed in thousands) for the different latitudes.

It will be seen at a glance what enormous differences there are in the curves representing the two phenomena; faculæ and prominences do not march in full accord. In the years 1895 and 1896 not only does an almost complete absence of promi-

[1] This JOURNAL, **2**, 119; **4**, 205.

TABLE I.

Day of the month	January: Groups of spots and pores	January: Spots	January: Pores	January: Faculæ	January: Prominences	February: Groups of spots and pores	February: Spots	February: Pores	February: Faculæ	February: Prominences	March: Groups of spots and pores	March: Spots	March: Pores	March: Faculæ	March: Prominences
1	..	..	..	..	..	3	5	21	..	8	5	13	47	10	4
2	4	3	15	..	3	5	5	26	11	7	6	12	54	12	2
3	4	2	15	8	4	6	9	18	..	..	7	9	58	..	..
4	4	5	11	..	8	..	..	..	..	..	7	13	67	10	8
5	8	2	31	..	..	..	..	..	..	..	6	17	45	..	4
6	6	8	16	..	..	5	5	13	..	..	4	6	78	10	0
7	5	5	4	..	2	4	4	27	..	3	4	6	20	..	1
8	3	4	5	..	4	6	5	39	12	5	5	4	13	11	2
9	5	4	4	..	..	4	4	17	..	..	3	2	7	13	3
10	..	..	..	..	..	4	2	11	13	3	4	4	11	11	2
11	2	1	4	13	1	3	2	10	..	0	..	..	..	..	..
12	1	2	0	12	0	3	3	13	12	1	3	1	8	11	..
13	3	1	21	11	4	3	4	21	..	2	4	3	11	..	7
14	3	1	6	10	1	6	3	29	11	2	4	3	4	..	5
15	..	..	..	..	..	3	6	11	..	0	6	2	10	9	4
16	2	1	2	10	5	3	3	12	9	3	3	1	4	10	2
17	1	1	0	..	2	1	2	7	12	2	2	1	4	11	3
18	2	2	0	..	2	2	3	3	13	4	..	..	..	..	..
19	2	2	3	9	5	3	4	6	15	..	..	..	..	..	..
20	2	2	3	11	5	..	..	..	..	..	6	4	9	..	..
21	2	2	0	10	6	..	..	..	..	..	5	2	13	..	0
22	2	2	0	9	7	..	..	..	..	..	5	2	35	..	4
23	..	..	..	..	..	..	..	..	..	..	5	5	34	..	4
24	..	..	..	..	..	..	..	..	..	..	6	3	37	15	3
25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
26	5	3	6	..	..	6	16	91	14	..	6	7	18	..	..
27	..	..	..	..	..	5	19	77	14	5	3	5	16	11	1
28	5	8	17	..	..	6	16	61	..	5	3	6	12	7	8
29	..	..	..	..	..	5	14	68	12	5	..	..	..	..	..
30	4	3	12	..	..	..	..	..	..	..	..	..	..	..	..
31	4	5	8	11	8	..	..	..	..	..	4	7	37	7	2

Day of the month	April: Groups of spots and pores	April: Spots	April: Pores	April: Faculæ	April: Prominences	May: Groups of spots and pores	May: Spots	May: Pores	May: Faculæ	May: Prominences	June: Groups of spots and pores	June: Spots	June: Pores	June: Faculæ	June: Prominences
1	6	11	36	..	1	3	2	13	8	2	3	6	33	..	..
2	..	..	..	..	..	2	0	24	8	0	4	5	18	..	3
3	7	14	58	..	5	1	1	29	11	2	5	4	12	..	..
4	8	11	48	..	..	2	2	9	..	..	4	3	8	..	..
5	8	11	30	13	4	3	4	11	13	0	4	2	7	9	..
6	6	13	25	..	4	3	2	9	8	3	4	2	3	10	2
7	6	13	21	..	4	2	2	15	7	4	3	2	10	..	1
8	3	12	7	..	..	4	0	22	..	4	3	2	6	..	5
9	3	7	36	..	3	4	0	2	12	9	4	5	8	..	..
10	..	..	..	..	..	2	2	6	8	4	4	10	7	..	4
11	2	6	9	..	..	3	0	9	10	..	4	10	29	..	..
12	1	3	8	11	0	2	0	3	..	..	4	11	34	11	4
13	1	2	3	14	1	2	0	6	10	4	3	12	28	..	4
14	0	0	0	9	2	1	0	1	..	4	2	8	28	8	4
15	0	0	0	11	..	1	0	1	10	2	4	7	41	9	3
16	0	0	0	..	..	0	0	0	9	3	6	11	32	10	1
17	0	0	0	..	..	1	0	2	10	5	..	..	..	..	..
18	1	0	1	11	1	2	0	8	9	2	3	5	13	12	6
19	1	2	8	..	..	1	1	7	12	4	2	1	5	13	3
20	3	2	24	..	4	1	2	9	11	..	3	2	18	10	3
21	5	1	42	15	2	2	1	11	13	3	1	3	8	10	4
22	6	3	27	11	3	3	1	14	13	2	3	4	13	10	5
23	6	2	25	15	1	3	1	9	..	7	3	5	52	15	3
24	3	1	23	10	2	..	..	..	..	..	3	8	54	12	5
25	4	4	13	10	4	..	..	..	..	..	2	8	35	7	9
26	4	3	22	10	1	..	..	..	..	..	2	9	22	..	..
27	4	4	31	10	3	5	3	38	13	4	..	..	..	..	..
28	4	2	26	..	..	5	7	37	13	..	3	5	10	..	..
29	..	..	..	..	..	4	5	23	..	1	2	4	16	7	6
30	5	1	14	13	2	4	4	24	..	3	3	5	7	11	10
31	..	..	..	..	..	2	6	9	..	..	..	..	..	..	..

TABLE I.—*Continued.*

Day of Month	July					August					September					October					November					December				
	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences
1......	3	4	27	13	4	1	1	3	8	..	4	4	26	9	8	2	3	7	13	7	3	1	14	..	..	2	4	16	13	2
2......	2	4	15	11	3	2	1	11	11	5	3	4	6	13	10	1	1	2	..	..	..	..	..	..	..	..	..	..	..	..
3......	3	4	15	..	5	1	1	4	9	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	6	17	..	..
4......	3	5	11	10	4	2	1	3	11	8	3	3	19	13	..	..	..	..	..	..	2	3	13	..	..	4	7	24	..	2
5......	4	5	12	10	8	2	2	5	..	3	4	2	9	11	6	0	0	0	13	..	2	5	14	..	..	5	9	37	14	3
6......	5	5	13	10	10	1	0	5	9	3	3	2	6	..	2	1	1	0	12	7	..	..	..	..	..	6	6	41	..	2
7......	4	3	25	9	6	0	0	0	10	3	2	3	8	10	3	1	1	0	10	9	..	..	..	..	..	4	8	12	..	..
8......	5	4	15	10	2	0	0	0	10	3	3	4	31	10	2	2	1	2	10	8	4	5	26	..	..	5	9	21	..	3
9......	4	3	9	10	6	2	1	2	12	5	5	9	47	8	4	1	1	0	9	9	..	..	..	..	..	5	8	39	19	6
10......	3	3	8	7	6	2	2	3	14	4	5	19	23	..	..	1	1	0	7	10	7	10	38	14	1	4	6	14	..	1
11......	5	2	16	9	7	2	1	2	14	3	6	18	30	7	6	2	1	5	7	10	7	12	44	14	3	3	8	3	..	2
12......	6	2	22	9	6	4	2	3	7	5	?7	18	16	..	5	2	1	20	11	8	6	12	34	..	1	3	2	32	12	..
13......	..	..	..	..	..	4	2	3	12	5	6	15	23	..	5	2	0	11	8	6	5	10	21	..	2	2	3	10	..	..
14......	..	..	..	..	..	3	3	6	11	9	6	14	50	10	3	2	1	13	..	..	7	16	33	..	..	..	..	..	..	..
15......	3	6	16	13	2	4	5	20	14	11	3	16	59	11	0	2	0	24	9	2	5	8	39	16	3	2	6	13	..	..
16......	4	9	14	..	5	4	6	27	..	6	4	20	101	8	4	3	3	17	..	2	..	..	..	..	..	3	4	24	15	2
17......	5	5	42	14	8	5	7	25	12	10	4	21	97	7	2	5	6	16	..	..	4	4	11	..	..	3	4	23	12	3
18......	4	9	49	15	4	5	4	24	12	3	3	16	93	8	3	4	7	24	12	..	4	1	21	..	..	3	7	18	15	..
19......	4	8	74	10	3	5	2	26	11	2	3	14	95	10	4	4	12	17	..	..	1	1	0	..	..	..	..	..	..	..
20......	6	8	46	14	5	6	1	26	..	6	4	19	68	11	5	4	9	28	..	..	1	1	6	9	6	..	..	..	..	..
21......	6	6	85	12	4	5	2	24	10	8	4	15	53	9	..	..	..	..	..	..	4	1	12	14	7	..	..	..	..	..
22......	4	4	48	8	5	3	5	25	..	3	4	10	61	11	3	4	5	27	..	..	3	5	13	..	..	4	9	33	..	2
23......	3	6	10	..	..	3	5	22	..	3	4	7	36	11	4	5	6	44	..	..	..	..	..	..	..	3	6	26	..	..
24......	..	..	..	..	..	3	7	17	..	8	5	6	58	9	7	5	9	11	..	..	..	..	..	..	..	3	4	22	..	..
25......	2	5	19	7	1	2	3	21	12	1	2	5	32	..	..	..	..	..	..	..	2	1	14	..	..	..	..	..	..	..
26......	2	3	5	..	2	2	1	10	..	..	2	4	17	..	..	4	3	14	..	5	2	3	15	..	..	..	..	..	..	..
27......	3	3	10	13	1	2	3	15	12	4	..	..	...	..	..	3	3	3	..	1	2	3	11	12	2	3	7	27	..	..
28......	2	2	11	14	3	3	4	20	..	10	1	3	9	6	5	3	2	17	12	3	3	2	16	13	7	..	..	..	..	..
29......	2	2	7	11	9	..	..	..	..	..	2	2	11	10	8	1	2	10	..	0	2	2	11	..	3	5	7	16	13	7
30......	1	1	7	10	7	4	4	24	11	8	3	2	11	13	9	2	3	10	11	1	..	..	..	..	..	7	6	19	12	4
31......	1	1	4	9	3	4	4	17	..	10	..	..	...	..	..	2	2	13	13	..	..	..	..	..	..	5	6	18	..	3

TABLE II.

Heliographic Latitude		Spots: First Quarter	Spots: Second Quarter	Spots: Third Quarter	Spots: Fourth Quarter	Spots: Year 1896	Faculæ: First Quarter	Faculæ: Second Quarter	Faculæ: Third Quarter	Faculæ: Fourth Quarter	Faculæ: Year 1896	Prominences: First Quarter	Prominences: Second Quarter	Prominences: Third Quarter	Prominences: Fourth Quarter	Prominences: Year 1896
North	80° to 90°	0	0	0	0	0	17	27	43	27	114	0	0	0	0	0
	70 to 80	0	0	0	0	0	22	38	74	31	165	0	0	0	1	1
	60 to 70	0	0	0	0	0	19	22	42	17	100	0	0	0	1	1
	50 to 60	0	0	0	0	0	20	19	26	8	73	4	17	26	14	61
	40 to 50	0	0	0	0	0	17	24	25	9	75	17	27	38	22	104
	30 to 40	0	0	0	0	0	25	27	31	22	105	22	39	70	17	148
	20 to 30	0	0	1	1	2	26	39	45	15	125	25	18	45	9	97
	10 to 20	15	11	11	2	37	38	54	57	37	186	17	7	21	11	56
	0 to 10	9	6	6	9	28	25	28	38	17	108	13	5	15	7	40
South	0° to 10°	7	15	6	11	38	23	36	34	24	117	19	12	18	9	58
	10 to 20	27	18	25	24	90	43	69	84	36	232	16	18	20	21	75
	20 to 30	7	6	2	1	15	25	30	55	32	142	19	15	40	19	93
	30 to 40	1	0	0	0	1	18	16	18	17	69	24	21	46	20	111
	40 to 50	0	0	0	0	0	14	8	21	10	53	10	14	34	10	68
	50 to 60	0	0	0	0	0	9	13	19	9	50	5	9	19	3	36
	60 to 70	0	0	0	0	0	37	21	19	12	89	0	2	0	1	3
	70 to 80	0	0	0	0	0	26	33	35	28	122	0	0	1	0	1
	80 to 90	0	0	0	0	0	16	31	39	23	109	0	0	0	0	0

TABLE III.

1896	Mean Frequency								
	of groups of spots and pores	of spots	of pores	of faculæ			of prominences		
				in northern hemisphere	in southern hemisphere	in both hemispheres	in northern hemisphere	in southern hemisphere	in both hemispheres
January	3.43	3.00	7.96	5.64	4.73	10.36	2.35	1.59	3.94
February	4.10	6.38	27.67	6.33	6.00	12.33	1.80	1.87	3.67
March	4.64	5.52	26.08	4.73	5.80	10.53	1.48	1.81	3.29
April	3.59	4.74	19.89	5.93	5.71	11.64	1.32	1.16	2.47
May	2.36	1.64	12.54	4.95	5.45	10.40	1.86	1.41	3.27
June	3.14	5.48	19.21	6.00	4.25	10.25	2.35	1.90	4.25
July	3.54	4.36	22.68	5.79	4.96	10.75	3.22	1.56	4.78
August	2.87	2.67	13.10	6.33	4.71	11.04	3.07	2.50	5.57
September	3.75	9.82	39.11	4.95	4.82	9.77	1.83	2.87	4.70
October	2.52	3.07	12.41	4.87	5.73	10.47	2.44	3.06	5.50
November	3.62	5.05	19.33	6.43	6.71	13.14	1.80	1.70	3.50
December	3.78	6.17	21.96	7.22	6.67	13.89	1.79	1.21	3.00
First Quarter ...	4.07	4.94	20.52	5.50	5.55	11.05	1.85	1.75	3.60
Second Quarter .	3.02	3.97	17.20	5.56	5.13	10.70	1.85	1.49	3.34
Third Quarter ..	3.37	5.55	24.69	5.69	4.84	10.52	2.76	2.28	5.04
Fourth Quarter..	3.25	4.66	17.55	5.90	6.16	12.06	2.05	2.07	4.12
Year	3.41	4.78	20.10	5.65	5.29	10.94	2.19	1.92	4.11

nences correspond to the polar maxima of faculæ, but it will also be seen that the other two maxima of the faculæ are nearer to the equator, since they fall between $\pm$ 10° and $\pm$ 20° and the others in much higher latitudes.

As a whole, the observations of these three years agree in so satisfactory a manner as to cast doubt on the correctness of the view that the seat of the two phenomena is the same; they lead us to admit only with reserve the opinion that the faculæ are identical with protuberances.

ON THE OBSERVATION AND KINEMATIC INTERPRETATION OF THE PHENOMENA DISCOVERED BY DR. ZEEMAN.

By M. A. Cornu.

The phenomena discovered by Dr. Zeeman relating to the action of a magnetic field on the radiations emitted by various luminous sources have given rise to some confusion, which seems to me to result from the optical imperfection of the methods of observation. The following arrangements give these phenomena with great clearness and leave no doubt as to the definitive conclusions announced by the author of the discovery.[1]

The luminous source is the flame of an oxyhydrogen burner playing upon a fragment of asbestos saturated with fused sodium chloride, or an induction spark taken between two metallic electrodes; it is placed between the two poles of an electro-magnet producing an intense magnetic field.

A vertical slit placed near the luminous source, or in the plane of a focal image of this source, directs the ray upon a concave Rowland grating of ten feet focus, which produces a bright line spectrum of the source. The spontaneously reversible lines are the ones which seem to show the phenomenon to the best advantage.

FIRST ARRANGEMENT.

One of these lines is observed in the focal plane of an ocular in which a steel needle is placed normally to the spectral lines. Behind the ocular is placed a doubly refracting Wollaston prism[2] which doubles the image of the needle; the diameter of this needle, though slightly conical, is so chosen that the two images

[1] Dr. P. Zeeman, "Doublets and Triplets in the Spectrum produced by external Magnetic Forces." *Phil. Mag.*, July 1897, p. 55; September 1897, p. 255; this Journal, May 1897.

[2] A rhomboid of spar might be used in place of the Wollaston prism; but there would be certain precautions necessary to avoid the effect of parallax arising from the inequality in distance of the planes of vision of the two images.

have a common edge. We thus obtain two adjoining fields, the one polarized parallel, the other perpendicular to the spectral lines.

1. *The ray is observed normal to the magnetic lines of force.*

The two poles of the electro-magnet (Faraday coils, ordinary Ruhmkorff model), terminating in two rounded cones, can be brought together to within 8^{mm} or 10^{mm}, and the observation is made in a plane perpendicular to the horizontal line which joins them.

The doubly refracting prism is adjusted in such a way that the spectral lines exhibit no discontinuity on the line of separation of the two fields when the strength of the magnets is zero.

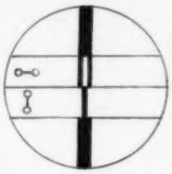


FIG. 1.

When the electro-magnet is excited the line is seen to widen; but in the two polarized fields the appearance of the line is modified. In the field where the polarization is parallel to the lines of force (line of the poles) the line is doubled, *i. e.*, a dark line appears in its center; in the other it is, on the contrary, narrower, and falls exactly on the prolongation of the dark line referred to above.[1] Reversal of the magnetic field does not affect the phenomenon in the least.

From this we may conclude that each single unpolarized line is transformed into a triplet, the exterior components of which are completely polarized parallel to the lines of force, while the central component is completely polarized in a perpendicular plane. The magnetic field thus produces two alterations of the

[1] When sodium light is used each of the lines D_1, D_2, may be more or less reversed, *i. e.*, more or less doubled: from this there results an apparent complication, but this does not affect the essential characteristics of the phenomenon.

original period, respectively equal and of contrary sign, and thus gives rise to two vibrations normal to the lines of force without modifying the period of the vibration parallel to these lines.

2. *The ray is observed parallel to the lines of force.*

One of the polar armatures is pierced in the line of the poles in order to permit the passage of the light following the direction of the lines of force. In order to make the observation, a quarter wave mica plate, the principal sections of which are at 45° with those of the prism, is placed between the ocular and the doubly refracting prism. As soon as the magnet is excited the line is seen in the two fields to become narrow and to break on the line of separation. (Fig. 2.) If the quarter wave plate is

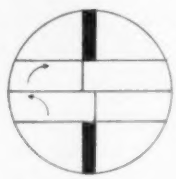


FIG. 2.

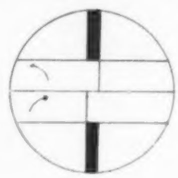


FIG. 3.

turned through 90° the displacement takes place in the opposite direction. (Fig. 3.) Reversal of the poles reverses the direction of the displacement. It is also noticed that the middle of the two lines thus produced occupies sensibly the position of the original line: the two alterations of the period are thus equal and of opposite sign.

The phenomenon is rendered more easily visible by placing side by side on the same glass plate two quarter wave plates with homologous rectangular sections; a slight to and fro motion of these plates gives alternately the two appearances mentioned above. A suitable rhythm increases still further the sensitiveness of the method; for when the eye is fixed upon the line of one of the regions the relative displacement of the corresponding line of the other region is *physiologically* doubled.

These observations prove that the action of the magnetic field separates each radiation into two rays circularly polarized

in opposite directions, the reversal of the poles reversing the directions of rotation of the circular vibrations. By determining the direction of rotation of each of these rays[1] it is possible to epitomize the various results in the very simple statement given further on.

SECOND ARRANGEMENT.

Instead of the long doubly refracting Wollaston prism (necessary in order to obtain two sufficiently broad fields) it is possible to utilize a single Nicol prism: the double field is then obtained with mica plates properly chosen and oriented.

1. *Ray observed normal to the lines of force.*

In the plane of the eyepiece are placed two half wave plates adjusted for the refrangibility of the bright line employed.[2] The upper plate has its upper section parallel or perpendicular to the direction of the spectral lines: the lower plate at $\pm 45^\circ$ to these lines. If the principal section of the Nicol prism is parallel or perpendicular to this direction the appearance (Fig. 1) is the same as with the first arrangement, since the second half wave plate turns through 90° the planes of polarization of the rays which it transmits.

2. *Ray observed parallel to the lines of force.*

In the focal plane of the eyepiece two quarter wave plates are placed: the upper plate with its principal sections at $+45^\circ$, the lower one at -45° to the direction of the lines; the Nicol prism being adjusted as before, the same appearance (Fig. 2) as with the first arrangement is obtained.

If it is desired to produce the rhythmical motion a second

[1] The correct determination is not so easy as might be supposed: one is in danger of committing the errors which Dr. Zeeman himself recognized (*loc. cit.* p. 58). In a technical publication (*l'Éclairage électrique*) I purpose to indicate various optical methods which permit this form of determination to be made practically and verified.

[2] The accurate adjustment of the double refraction of the mica plates also requires special care, regarding which particulars will be given in the appendix already referred to.

system is arranged in reverse order, and placed opposite the first in the order shown below:

+45°	−45°
−45°	+45°

Alternate motion of this system from right to left produces the reversal and the apparent duplication so favorable to the observation of the phenomenon.

KINEMATIC INTERPRETATION OF THE PHENOMENA.

The phenomenon as a whole can be stated in conformity with the rules of Fresnel and Ampère. These rules are as follows:

(1) A ray of ordinary light is the superposition of two independent rays equal in intensity and polarized at right angles to each other (Fresnel):

(2) A plane polarized ray is the superposition of two rays equal in intensity and polarized circularly in opposite directions (Fresnel).

(3) A magnetic line of force is equivalent to the axis of a solenoid, the south pole of which is to the left of the current (Ampère).

The action of a magnetic field on the emission of a radiation tends to decompose the rectilinear vibratory components capable of propagation by waves polarized circularly in a direction parallel to the currents of the solenoid.

The vibrations which rotate in the direction of the current of the solenoid are accelerated, those which rotate in the reverse direction are retarded.

This immediately explains the doublet observed along the lines of force. In the direction perpendicular to these lines this statement shows that the component parallel to the lines of force (wave polarized perpendicular to this direction) is unaffected: this is the central line of the triplet; the two outer lines polarized at right angles to this are more difficult to explain. However, their existence may be perceived geometrically: in fact, each

consists of two circular vibrations, one accelerated, the other retarded, in which the magnetic field doubles the component normal to the lines of forçe; there is mutual extinction or compensation of the two longitudinal components which cannot be propagated (the two waves polarized rectilinearly are produced by circular vibrations of opposite direction, seen in *section*).

This purely kinematical interpretation, although somewhat superficial, shows that the phenomenon discovered by Dr. Zeeman can be explained by considerations wholly independent of the electro-chemical ideas of Professor Lorentz, which are the origin of and are closely related to the vortex theories recently restored to favorable consideration.

It shows, moreover, the essential difference which exists between this phenomenon and that of the magnetic rotary power discovered by Faraday.

The action of the magnetic field on the sources where the waves are, so to speak, in a *nascent* state, affects the *period of vibration*, while in the experiment of Faraday it affects the *velocity of propagation* of luminous waves which have already acquired their permanent state.

I have convinced myself with the same arrangements, that the magnetic rotation of the plane of polarization is accompanied by no sensible variation of the vibration period of the monochromatic light employed, while I have previously demonstrated[1] that the velocity of propagation of two circular waves is modified: one is accelerated, the other is retarded, by equally sensible quantities, in the direction corresponding to Ampère's rule.

PARIS, October 1897.

[1] *C. R.*, **92**, 1365; the phenomena discovered by Dr. Zeeman permit the extension of variations of period of the conjectural law there announced (*loc. cit.*, p. 1307) for the variations of the velocities of two circular waves due to the doubling of a wave of rectilinear vibration.

CORRECTIONS AND ADDITIONS TO PROFESSOR H. A. ROWLAND'S TABLE OF SOLAR SPECTRUM WAVE-LENGTHS.

THE errors in wave-length have been carefully determined for the whole table, but the identification of solar lines with the lines of the elements in the spectrum of the electric arc has, at the present time, been carefully revised only from wave-length 3722 to 4175. Therefore the corrections and additions to the identifications have been given only for the more important lines between these limits. A very few small solar lines have been added to the table.

The changes in wave-length have been few, most of the changes in this table being additions to the identifications.

FIRST PART.

				Corrections and Additions		
Page[1]	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
8				2979.410[4]		0
8	2980.080		0 Nd	2980.080[4]		0 Nd
8	2983.764		000 N	2983.764[4]		000 N
8				2985.769[4]		000
8	2988.333		000 N	2988.333[4]		000 N
8	2988.873		000	2988.873[3]		000
8				2989.378[4]		0
9	3003.773[1]	-Ni	2 Nd ?	3003.773[2]	-, Ni	2 Nd?
9				3010.996[1]		2 d
14	3077.295 s	Fe	3	3077.295 } s	Fe	3
14	3077.332 s		1	3077.332 } s		1
18	3138.798	Zr	1	3138.789	Zr	1
21	3177.633	Fe ?	2	3177.653	Fe ?	2
23	3195.705 s	Ni	2	3195.705 s	Y-Ni	2
23	3200.407		2 Nd ?	3200.407	Y,-	2 Nd?
23	3203.435		1	3203.435	Y	1
24	3216.807		1	3216.807	Y	1
25	3223.378		1	3223.378	Mn	1
26	3242.395		1	3242.395	Y	1

[1] The page numbers refer to the reprint of the Table, which will soon be ready for distribution.

FIRST PART—*Continued.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
30	3286.784		0	3286.754		0
30	3289.498		4	3289.498	Eb?	4
32	3308.947		5	3308.947	Co, Ti	5
32	3309.065	Co, Ti	0000 N	3309.065		0000 N
32	3312.453	Co	2	3312.453	Ni	2
33	3328.016	Di ?	2	3328.016	Y	2
33	See note to	3335.192, 33	35.350, etc.	See note to	3335.299, 33	35.350, etc.
35	3353.875		4	3353.875	Sc,-	4
37	3372.901	Ti-Pd	5	3372.901 } d?	[1] Ti-Pd	10
37	3372.994		5	3372.994 }		
				[1] This is pro line which but is proba in the Sun.	bably a stro was measure bly a single l	ng titanium d as double, ine reversed
38	3385.167		0	3385.167	Y	0
40	3407.937	Di ?	0	3407.937	Y	0
43	3443.791	Co	5 d?	3443.791	Co, Ti	5 d?
47	3496.224	Co	0	3496.224	Co, Y	0
53	3565.535 s	Fe	20	3565.535 s	Fe	12
54	3572.712	-, Sc	6	3572.712	Sc,-	6
62	3683.182	Co	3	3683.182 } s	Co	3
62	3683.229	Fe-v	4	3683.229 }	Fe-V	4
62.	3683.761		2	3683.761	Fe	2
63	3685.810		0000	3685.800		0000
63	3694.344		3	3694.344	Eb?	3
64	3706.175	Mn	6 d ?	3706.175	Ca, Mn	6 d ?

SECOND PART.

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
	3722.174		2	3722.174[1]	Fe ?	2
4	3725.638		3	3725.638	Fe,-	3
4	3727.061	Mn	4d ?	3727.061	Fe, Ru-Mn	4d ?
4	3727.965		2	3727.965	Fe	2
4	3728.183		1	3728.183	Ru	2
4	3728.813	Ti-Fe	2	3728.813	Fe-Ti	2
4	3730.534	Fe	3	3730.534	Fe, Ru	3
4	3732.545 s	Ti-Fe-Co	6	3732.545 s	Co, Fe	6
5	3737.059 s	Ca-Mn	5	3737.059 s	Mn-Ca	5

[1] See remarks at the beginning of this Table.

SECOND PART—*Continued.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5	3743.508 s	Fe	6	3743.508	Fe-Ti	6
5	3743.626	Ti	2	3743.626		2
5	3745.617	Ti	1	3745.617	Ti	1
5	3745.717 s	Fe	8	3745.717 s	Fe	8
5	3746.058 s	Fe	6	3746.058 s	Fe	6
5	3746.191	Ni	0	3746.191	Ni	0
6	3753.732	Fe-Ti	6	3753.732	Fe-Ti	6 d ?
6	3758.269		00	3758.269		00
6	3758.375 s	Fe	15	3758.375 s	Fe	15
6	3759.215	Zr	1	3759.215	La, C	1
6	3759.297	La-Fe	2	3759.297	Fe, C	2
7	3767.493		1 N	3767.493	Ru,-	1 N
8	3787.304	Fe-C	1	3787.304	C-Fe	1
8	3788.839		2	3788.839	Y	2
9	3789.553	Fe	1 N	3789.553	Fe,-	2 N
9	3799.934	V	1	3799.934		1
9	3800.046 s		0	3800.046	V	0
10	3804.151	Fe	3	3804.151 s		3
10	3804.934	Fe-Cr-C	2	3804.934	Cr-C	2
10	3807.681	Fe	6	3807.681	V-Fe	6
10	3811.945	Fe	2	3811.945		2
10	3812.033		2	3812.033	Fe	2
11	3814.671	Fe-C	4	3814.617	Co.Fe-C	4
11	3817.523	Co-Ti-C	0	3817.523	-C	0
11	3824.441		2	3824.441	Fe	2
12	3825.543		2	3825.543	Cr	2
12	3826.555		1	3826.555	Cr	1
12	3827.714		2	3827.714	Fe	2
12	3829.617	Ti-C	2	3829.617	Fe, Ti-C	2
12	3829.728	Fe-C	0	3829.728	-C	0
12	3829.822	Ti-C	1	3829.822	Mn, Ti-C	1
12	3831.002	Fe	2	3831.002	C-Fe	2
12	3833.026		3 N	3833.026	-, Ni	3 N
12	3834.006	Mn-C	3	3834.006	C-Mn-Rh	3
12	3836.905		1	3836.905	Zr ?, Ti	1
12	3837.277		2	3837.277	Fe	2
13	3843.854		2	3843.854	Co,-	2
13	3845.606	Co-C	8 d ?	3845.606	C-Co	8 d ?
13	3849.501	C ?	1 N	3849.501	C-Cr	1 N
13	3849.675		1	3849.675	Cr	1
13	3850.118	Fe	10	3850.118	Fe-Cr	10
14	3852.347	Cr, C	1	3852.347	Cr, C	1
14	3855.450	V	2	3855.450	Cr, V	2
14	3855.547		1	3855.547	C,-	1
14	3857.805	C ?	6 d ?	3857.805	Cr-C	6 d ?
14	3858.262		1 N	3858.262	-, Ti	1 N
14	3860.767	C-Ni	3 N	3860.767	Ni, C	3 N
15	3866.577	C-	1	3866.577	C-Ti	1

SECOND PART—*Continued.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and character	Wave-length	Substance	Intensity and character
15	3868.060	-C	2	3868.060	Fe, C	2
15	3873.065	-C	2	3873.065	Fe-C	2
16	3874.651		2	3874.651	-, Cr	2
16	3876.194	Fe	5	3876.194	Fe, V	5
16	3879.331	C	1	3879.331	Cr, C	1
16	3883.033	C	1	3883.033	C, Ti	1
16	3883.426	C-	2	3883.426	C-Fe	2
17	3884.748	Ca	1	3884.748	Co	1
17	3885.364	Fe, Cr	2	3885.364	Cr	2
17	3886.568	V	0	3886.568	La	0
17				3886.704	V	000
17	3886.942	Cr	3	3886.942	Cr, Mo	3
17	3889.374		1Nd?	3889.374	-, Ba	1Nd?
17	3890.068		1	3890.068	Nd, Ce	1
17	3890.707		1N	3890.707	Nd,-	1N
17	3891.918		0	3891.918	Ba	0
17	3892.069	Fe	4	3892.069	Cr, Fe	4
17	3894.165	Cr	3	3894.165	Fe, Cr, V?	3
18	3900.681	T - Fe-Zr	5	3900.681	Ti-Fe	5
18	3902.002		3	3902.002	Nd-	3
18	3902.114	Fe	1	3902.114		1
18	3903.090	Fe, Cr	10	3903.090	Cr,-Fe, Mo	10
18	3903.302		1	3903.302	Cr	1
18	3903.398		2	3903.398	V-Ce?	2
18				3904.310	V	000
18	3905.017		1	3905.017	Mn,-	1
18	3905.146		1	3905.146	Mn-	1
18	3906.044		3	3906.044	Nd,-	3N
18	3907.807		1	3907.807	Fe, Ti?	1
18	3907.910		1	3907.910	Cr, Nd	1
18	3909.976	Fe	5	3909.976	Fe, V	5
18	3910.079	Co-Ca	3Nd?	3910.079	Ba, Co	3Nd?
19	3913.609	Ti-Fe	5d?	3913.609	Ti-	5d?
19	3921.105		0	3921.105	Nd	0
19	3921.188	Cr-Nd	3	3921.188	Cr-	3
19	3921.855	Zr-Mn	4	3921.855	Ce, Mn-Zr	4
19	3923.180		1	3923.180	Pt, Ce	1
20	3925.347 s	Co, Fe?	4	3925.347 s	Co, Fe?-V	4
20	3928.357	Cr?	2Nd?	3928.357	-, Mn	2Nd?
20	3929.363	Fe-La-Mn	2	3929.363	Fe-La-Mn-Co	2
20	3929.497	Co?	1	3929.497		1
20	3933.523		8N	3933.523		[1]8N
20	3934.108	Co-	8N	3934.108	Co, V-Zr	[1]8N
20	3934.174		0N	3934.508	Ti, Cr?	0N
20	3938.439		2	3938.439	-, Cr	2
20				[1] Mostly shading of K.		
21	3941.323		1	3941.323	Cr, V	1
21	3941.637	Cr	3	3941.637	Cr, Nd	3
21	3941.997		1	3941.997	-Mn	1

SECOND PART—*Continued.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
21	3942.157	Mn?-	oN	3942.157	V-	oN
21	3943.721		I	3943.721	V,-	I
21	3948.818	Ti	4	3948.818	Ti, V	4
21	3951.219	Cr	I	3951.219	Cr, Nd	I
21	3952.103	Mn-	2	3952.103	Mn, V	[1]2
21	3952.342	Na?	0	3952.342	Nd	0
21	3952.754	Fe	4	3952.754	Ce-Fe	4
21	3952.894		0	3952.894	Mn, Nd?	0
21	3953.043	Mn	3	3953.043		3
21				[1] This V line weak in V Cl from Tromsdorff.		
22	3955.524		00	3955.624		00
22	3956.476	Co,-Ti	4	3956.476	Ce, Co-Ti	[1]4
22	3958.355	Ti, Zr	5	3958.355	Zr, Ti, Ce	5
22	3959.972		I	3959.972	Ce,-	I
22	3964.663	Fe	3	3964.663	Ce Fe	3
22	3964.897	Fe?	0 Nd?	3964.897		0 Nd?
22	3966.647	Ni, Fe	2	3966.647		2
22	3966.778	Fe	3	3966.778	Fe, Zr	3
22	3968.350		6 N	3968.350	-,Zr	[2]6 N
22	3968.854	Fe? [1]	I N	3968.854		I N
22				[1] Ce and Co a faint side line.		
22				[2] Mostly shading of H.		
23	3968.886		6 N	3968.886		[2]6 N
23	3970.419		I	3970.419	Fe?	I
23	3970.540		2	3970.540	Fe	2
23	3970.631		I	3970.631	Ni	I
23	3973.262	Co	I	3973.262		I
23	3973.796	Fe	I	3973.796	Nd, V, Fe	[3]I
23	3974.536	Fe	3	3974.536	Fe, Ni	3
23	3974.637	Ni?	2	3974.637		2
23	3975.506	Co-	I	3975.506	Rh-Co, V?	I
23	3977.009	Fe	2	3977.009	Nd-Fe	2
23	3978.809	Co, Cr	3	3978.809	Co-Cr, Ce	3
23	3979.664	,-Co	4	3979.664	Nd-Co	4
23				[2] Mostly shading of H.		
23				[3] V line weak in V Cl.		
24	3981.662		00	3981.662	-,Zr?	00
24	3981.762	Zr?	0	3981.762		0
24	3982.630	Ti-Mn	2	3982.630	Ti	2
24	3982.742	Y	3	3982.742	Mn-Y	3
24	3983.341		2 N	3983.341	-,Cr	2 N
24	3985.385		0	3985.385	Mn	0
24	3985.463	Mn	I	3985.463		I
24	3985.539	Fe	5	3985.539	Fe	3
24	3986.321	Fe	3	3986.321	Fe-Nd	3
24	3988.114		0	3988.114	Eb?	[2]0
24	3990.129	Cr-Mn	I	3990.129	Mn-Cr	I
24	3991.690	Co	0	3991.690	Co-Mn	0

SECOND PART—*Continued.*

				Additions and Corrections		
Page	Wave-lengths	Substance	Intensity and Character	Wave-lengths	Substance	Intensity and Character
24	3991.830	Co-Cr	2	3991.830	Cr, Co	2
24	3992.538	Fe	1	3992.538	Fe, Ce	1
24	3994.092	Cr	1 .	3994.092	Ni?	1
24	3994.160	Ni	1	3994.160	Cr	1
24				[2] There is a strong metallic line at 3988.140, which is supposed to be due to erbium, but it is probably not coincident with the solar line.		
25	4001.315		3	4001.315	Mn,-	3
25	4005.202		1	4005.202	Fe	1
25	4005.632		1	4005.632	Fe	1
25	4005.856		3	4005.856	V	[1] 3
25				[1] This V line is weak in V Cl from Tromsdorff		
26	4009.694	Fe	1	4009.694		1
26	4010.327	Fe	1	4010.327	Ce-Fe	1
26	4012.541	Ti	4	4012.541	Ti, Ce	4
26	4017.620	Ni ?	2	4017.620		2
27	4021.057	Co	3	4021.057	Nd-Co	3
27	4021.893	Ti	0	4021.893	Nd	0
27	4022.018	Fe	5	4022.018	Ti-Fe-V	5 d ?
27	4023.533	Co-	3	4023.533	V, Co	[2] 3
27	4025.286	Ti-	3	4025.286	Ti-Ce	3
27	4028.497	Ti-	4	4028.497	Ti-Ce	4
27	4028.912	Fe-Ce	1	4028.912	Fe	1
27	4030.646	Fe-Ti	5	4030.646	Nd-Fe-Ti	5
27	4030.878 } s	Mn	[1] { 4	4030.878 } s		
27	(4030.918) } s			(4030.918) } s	Mn	[3] 10 d ?
27	4030.947 } s	Mn	5	4030.947 } s		
27	4031.048		2	4031.048	Fe ?	2
27	4031.865	Fe-La	2	4031.865	La,-	2
27	4031.942	Mn	2	4031.942	Fe?, Nd, Mn, V	2
27	4033.224 s	Fe-Mn	[1] 7 d ?	4033.224 s	Mn	[3] 8 d ?
27	4033.337		1	4033.337	Fe ?	1
27				[2] V line weak in V Cl from Tromsdorff.		
27				[3] Apparent duplicity caused by reversal in Sun.		
28	4034.644 s	Mn-Fe	[1] 6 d ?	4034.644 s	Mn	[2] 6 d
28	4036.923		1	4036.923	V,-	1
28	4037.837		1	4037.837	Ce,-	1
28	4043.839		0	4043.839	Cr	0
28	4043.956	Cr	0	4043.956	Ti	0
28	4044.644		1	4044.644	-, Zr	1
28	4045.371	Mn	1 N	4045.371	Ce, Mn	1 N
28	4045.748		2	4045.748	-, Zr, W?	2
28	4047.338	K ?	00 Nd ?	4047.338	-K	00 d
28	4047.461	Fe	2	4047.461	Ce-Fe	2
28	4048.224		1 N	4048.224	Cr-	1 N

SECOND PART—*Continued.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
28				[2]Apparent duplicity caused by reversal in Sun.		
29	4049.822		1 Nd ?	4049.882	-, Cr	1 Nd ?
	4052.603	Mn	2	4052.603	Mn, Fe	2
	4052.650	Fe	3	4052.650		3
	4053.981	Fe-Ti	3	4053.981	Cr-Fe-Ti	3
	4054.962		2	4054.962	Fe	2
	4055.189	Ti-Fe	3	4055.189	Ce-Ti-Fe,Zr	3
	4058.372	Co-Fe	4	4058.372	Ti, Co-Fe	4
29	4061.881	Mn	[1] { 2 Nd	4061.781	Mn	[1] 2 Nd
29	4062.105		{ 2	4062.105		2
30	4064.361	Ti	1	4064.361	Zr-Ti	1
30	4067.139	Fe	5	4067.139	Cr-Fe	5
30				4068.555	Cr	000
30	4069.761		1	4069.761	V,-	1
30	4071.680	Fe	1	4071.680	Fe, V	1
30	4072.295		00 N	4072.295	-, V?	[2] 00 N
30	4073.921 s	Fe	4	4073.921	Ce, Fe	4
30	4078.515	Fe	4	4078.515	Zr-Fe	4
30				[2] This line is probably variable in the solar spectrum.		
31	4080.368	Fe, Nd	3	4080.368	Fe, Nd, Cr	3
31	4081.415	Fe	1	4081.415		1
31	4083.095	Mn	4	4083.095	V-Mn	4
31				4084.300	Cr	000
31	4085.408		1	4085.408	-, Ce	1
31	4086.133		1	4086.133	Fe?	1
31	4091.109		3	4091.109	Ce-	3
31	4092.547	Co, Mn	3	4092.547	Co, Mn, V	3
31	4092.821	[1] V, Ca	3 d?	4092.821	[1] V, Ca	3 d?
31				[1] These lines coincide with the heads of bands due to calcium. The bands probably become lines owing to the weak dilution of calcium vapor in the Sun.		
32	4096.262	Fe	2	4096.262	Fe, Nd	2
32	4098.689	[1] Ca?	4	4098.689		4
32	4098.746		2	4098.746	[1] -, Co?	2
32				4101.531		000
32	4101.840		3	4101.840	Fe?	3
32				4105.019	Cr	000
32	4107.649 s	Ce-Fe-Zr	5	4107.649 s	Ce-Fe	5
32	4109.905	[1] V	2	4109.905	V	[2] 2
32				[2] One of the strongest Vanadium lines.		
33	4111.021	Mn	1	4111.021	-, Mn	1
33	4111.154	Mn?	1	4111.154		1
33	4116.707	[1] V	0	4116.707	V, Fe?	0
33	4116.859	Nd?	1	4116.859		1
33	4116.974		00	4116.974	Nd?	00

SECOND PART—*Continued.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
33	4119.550	Fe	1	4119.550	C?-Fe-V	1
33	4123.384	[2] La	12	4123.384	[2] La	1
33	4123.539	V	0	4123.539	Cr	0
33	4123.664	Mn	1	4123.664	Ce, V-Mn	1
34	4126.200	V	000	4126.200		000
34	4126.344	Fe	4	4126.344	V-Fe	4
34	4127.957	Fe	4	4127.957	Ce-Fe	4
34	4128.251	V-	6 d	4128.251	Ce-V,-	6 d
34	4131.271	Mn	1	4131.271	Ce, Mn	1
34	4132.235	Fe	10	4132.235	Fe-Co	10
34	4134.589	V-Fe?	3	4134.589	Fe?	3
34	4134.675		1	4134.675	V	1
35	4137.809	Fe, Ce	1	4137.809	Ce	1
35	4140.400	Fe?	0	4140.400		0
35	4140.558		3	4140.558	-, Fe?	3
	4141.809	La	0	4141.809	-, La	0 N
				4141.910	La	0000
35	4143.664		2	4143.664	-, Mo	2
35	4147.645	Mn	1	4147.645		1
35	4147.677		000	4147.677	Mn	00
35	4149.360	Zr	2	4149.360	C, Zr	2
36	4150.964	Ce	00N	4150.964		00N
36	4151.129	Zr, Ti	1	4151.129	Ce-Zr, Ti	1
36	4152.108	Fe, La	2	4152.108	Fe, La, Ce	2
36	4152.242	Ce?	1	4152.242		1
36	4154.265		2	4154.265	-, Fe ?	2
36	4162.623		1N	4162.623	C, -	1N
37	4162.825		1N	4162.825	Ce, C	1N
37	4163.818	Ti, Cr	4	4163.818	Cr-Ti,-	4
37	4165.550	Fe	3d ?	4165.550	C, Fe	3d
37	4165.759	Ce,-	2	4165.759	-, Ce	1
37	4167.737		1Nd ?	4167.737	Y-Ru ?	1Nd ?
37	4168.025		2	4168.025	Ce-Fe	2
37	4168.133	Ni	2	4168.133	Ni, C	2
37	4171.854 [1]	Cr, La, Mn, Ni, Fe	2	4171.854	C, Fe ?	2
37	4172.211	Al ?	1	4172.211	Al	1
37	4172.296	Fe	2	4172.296	Fe-Ce	2
37	[1] Probably due to some common impurity of unknown origin. Is it Al? or Si? The gallium line is also in this region, but I have no specimen of gallium with which to determine its exact position. The Fe line is strong enough alone to account for it.			[2] Note at bottom of page 37 should be struck out. The line is mostly if not wholly due to carbon (or cyanogen).		
38	4177.698	Fe	3	4177.698		3
38	4177.772		3	4177.772	Fe*	3
40	4207.566	Fe	1N	4207.566	C	1N

*See remarks at the beginning of this Table.

SECOND PART — *Concluded.*

				Corrections and Additions		
Page	Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
41	4233.328	Mn-Fe	4	4233.328	Mn	4
42	4239.890	Mn	3	4239.890	Fe, Mn	3
42	4246.996	Y?	5	4246.996	[1] Sc	
				[1] One of the spectrum of	strongest li scandium.	nes in the
45	4280.027		1	4280.027	Fe,-	1
45	4280.374		1	4280.374	-, Fe	1N
45	4285.966		1	4285.966	Co	1
45	4288.310	Ti	1	4288.310	Ti, Fe	1
46	4299.803	Ti	2	4299.803	Fe, Ti	2
46	4304.729		2	4304.729	Fe,-	2
56	4455.980	Mn	2	4455.980 } s	Mn	2
56	4456.064 s	Ca	3	4456.064 } s	Ca	3
56	4459.525	Fe, Cr	1	4459.525	Cr	1
57	4464.938		1	4464.938	Fe	1
58	4482.338	-, Fe	5	4482.338	Fe,-	5
59	4497.023 s	Cr	3	4497.023 } s	Cr	3
59	4497.138	Zr	0	4497.138 } s	Zr	0
59	4501.448	Ti,-	5	4501.445	Ti,-	5
62	4546.129	Fe, Cr	3	4546.129	Cr	3
80	4914.150		2	4914.150	Ni	2
81	4934.214 } s	Ba	3	4934.214 } s	Ba-Fe ?	6
81	4934.277 } s		4	4934.277 } s		
				[1] This is prob another nar iron) at the	ably a bariu rower line red edge.	m line with (probably
92	5209.779		0000	5209.779		0000
96	5328.696	Fe	2	5328.696	} [1] Fe	5
96	5328.696	Fe	2	5328.696		
				[1] Measured as versed in	double, but Sun.	probably re-
109	5646.039		00	5646.049		00
110	5682.427		2	5682.427	Ni	2
111	5693.330		0000	5693.350		0000
113				5754.222	A ?	000
114	5788.990	A (O)	00	5788.983	A (O)	00
114	5789.418 [1]	A (O)	od	5789.415[1]	A (O)	od
118				5889.972	A (wv)	1N
118	5896.155	Na	20	5896.155D_1s[3]	Na	20
118	5896.35D7$_1$s[3]		ooN	5896.357		ooN
120	5918.635	A (wv)	4	5918.635	A (wv)	4d
122	5974.094	N	0000	5974.094		0000N
122	5974.812	N	0000	5974.812		0000N
126	6090.429	Fe	2	6090.429	Ti, V	2
129	6252.773 s		7	6252.773 s	Fe	7
131	6298.666	Co, A (O)	2	6298.666	Ni, A (O)	2
136	6609.360 s		3	6609.360 s	Fe	3
146	7140.568	A	000N	7140.560	A	000N

RESEARCHES ON THE SPECTRUM OF THE VARIABLE STAR η AQUILÆ.

By A. Bélopolsky.

At a meeting of the Academy of Sciences of St. Petersburg, on September 27, 1895, I presented some preliminary researches on the spectrum of the star η Aquilæ, the magnitude of which lies between 3.5 and 4.7. I had found with a single prism spectrograph that the star has a periodically variable velocity in the line of sight; but the unfavorable time, the low position of the star (merid. alt. = 30°), and the small dispersion of the spectrograph did not allow me to carry the researches further.

This year our great refractor has a correcting lens for the chemical rays, and our two-prism spectrograph by Halle has been provided with a large collimator. These two arrangements have enabled us to obtain spectrograms of stars down to the 4.5 magnitude, without prolonging the exposure beyond one hour, so that under favorable atmospheric conditions we obtain satisfactory spectrograms of variable stars like β Lyræ, η Aquilæ and δ Cephei in all their phases of brightness.

The twelve spectrograms of the star η Aquilæ obtained during the present summer fully confirm my earlier researches concerning this star.

All the measures have been carried out with reference to the spectrum of iron, by means of a solar spectrogram, which is placed on the spectrogram of the star during the process of measurement. In this manner are obtained (1) the differences of settings on the lines of the star and of the Sun; (2) the differences of settings on the lines of the artificial spectrum and of the Sun; (3) the differences of settings on the lines of the star and on the lines of terrestrial iron; *i. e.*, the immediate displacements.

These differences give two methods for finding the displacement of any line. It is only necessary that the line should be found in the spectrum of the Sun, as in the case of the line

$H\gamma$. By means of these differences we construct three kinds of curves, wave-lengths being measured along the axis of x, and differences along the axis of y. The sum of the ordinates for a given line (*e. g.*, $H\gamma$) of the first two curves gives the displacement of that line. The ordinates of the third curve, for the selected ray, give the direct displacement. This method allows us to determine the displacement even of lines which are not represented by terrestrial lines in the spectrogram. It also allows us to use the line λ 4481.16 in the spectra of I type stars, where it is in most cases more easily measured than the diffuse lines of hydrogen.

The spectrum of η Aquilæ belongs to a type intermediate between II and III. Its resemblance to the spectrum of the variable star δ Cephei is remarkable.

In the measurements the following lines have been used.

λ4251	double	λ4315	good
4272	double	4319	rather wide
4308	good	4322	rather wide
4313	distinct, narrow	4384	good ; narrower than in type II
4314	good	4405	the most distinct line
		λ4415	broader than in spectra of type II

In the following table are given the differences d_1, of the micrometer readings for the stellar and the solar lines ; also, the differences d_2 for the lines of the artificial spectrum and those of the Sun. The displacement d_3 of the $H\gamma$ line $=d_1+d^2$, where d_1 and d_2 are determined graphically by the method already described. The value of d_3 is also obtained immediately from the differences of readings on the terrestrial and stellar lines, in which case it is denoted by d_4

1897—July 10.

λ	d_1	d_2	λ	d_1	d_2		
4272	—0.450	0.268	4322	—0.467		$d_1=$	—0.474
4275	0.447		4326		0.315	$d_2=$	0.321
4308	0.469	0.291	4384	0.483	0.353	$d_3=$	—0.153
4315	0.460		4405	0.497	0.374	$d_4=$	—0.153
4319	0.474		4415		0.362		
			4427	0.488			

1897—July 11.

λ	d_1	d_2	λ	d_1	d_2	
4251	—0.528	0.327	4319	—0.507		$d_1 =$ —0.530
4272		0.348	4322	0.535		$d_2 =$ 0.383
4275	0.517		4326		0.384	$d_3 =$ —0.147
4288	0.553		4384		0.414	$d_4 =$ —0.156
4295	0.536	0.344	4405	0.540	0.420	
4308	0.516	0.348	4415	0.513	0.405	
4314	0.553		4427	0.519		

1897—July 12.

λ	d_1	d_2	λ	d_1	d_2	
4272		—0.369	4322	0.242		$d_1 =$ 0.242
4275	0.249		4326		—0.350	$d_2 =$ —0.346
4308	0.238	0.371	4384		0.319	$d_3 =$ —0.104
4315	0.232		4405	0.225	0.307	$d_4 =$ —0.114
4319	0.246		4415	0.269	0.329	

1897—July 13.

λ	d_1	d_2	λ	d_1	d_2	
4272		—0.378	4368	0.248		$d_1 =$ 0.251
4308	0.268	0.354	4370	0.221		$d_2 =$ —0.325
4315	0.255		4384		—0.301	$d_3 =$ —0.074
4322	0.210		4405	0.253	0.297	$d_4 =$ = 0.064
4326	0.252	0.315	4415	0.291	0.319	
4352	0.241		4427	0.281		

1897—July 17.

λ	d_1	d	λ	d_1	d_2	
4202	0.084	—0.255	4326	0.091	—0.220	$d_1 =$ 0.092
4261	0.021	0.214	4384	0.096	0.205	$d_2 =$ —0.214
4272	0.078	0.226	4395	0.092		$d_3 =$ —0.122
4295	0.083		4405	0.092	0.204	$d_4 =$ —0.126
4808	0.100	0.239	4415	0.171	0.217	
4321	0.100					

1897—July 21.

Weak spectrogram. The lines λ4405 and λ4415 are distinct, and give the following values of d_4:

λ4405 $d_4 =$ —0.046

λ4415 $d_4 =$ —0.036

1897—July 22.

λ	d_1	d	λ	d_1	d_2	
4275		−0.114	4326		−0.124	$d_1 =$ 0.127
4308		0.168	4384		0.137	$d_2 =$ −0.127
4315	0.135		4400	0.103		$d_3 =$ 0.000
4319	0.111		4405	0.118	0.136	$d_4 =$ +0.010
4322	0.142		4415	0.157	0.119	
			4427	0.136		

1897—July 25 (1st meas.)

λ	d_1	d_2	λ	d_1	d_2	
4261	−0.222	0.029	4322	−0.182		$d_1 =$ −0.207
4272		0.019	4326		0.069	$d_2 =$ 0.077
4275	0.223		4368	0.184		$d_3 =$ −0.130
4308	0.195	0.033	4384		0.102	$d_4 =$ −0.148
4313	0.207		4405	0.238		
4314	0.199		4415	0.199		

1897—July 25 (2d meas.)

λ	d_1	d_2	λ	d_1	d_2	
4272		0.034	4319	−0.216		$d_1 =$ −0.208
4308	−0.210	0.042	4326		0.075	$d_2 =$ 0.076
4313	0.212		4384		0.112	$d_3 =$ −0.132
4314	0.206		4405	0.214	0.115	$d_4 =$ −0.139
			4415	0.209		

1897—July 25 (2d spectrogram.)

λ	d_1	d_2	λ	d_1	d_2	
4272	−0.063	−0.074	4326		−0.025	$d_1 =$ −0.094
4308	0.080	−0.065	4384		+0.001	$d_2 =$ −0.027
4313	0.113		4405	0.117	+0.016	$d_3 =$ −0.121
4319	0.084		4415	0.098	+0.026	$d_4 =$ −0.125
4322	0.098					

1897—July 26.

λ	d_1	d_2	λ	d_1	d_2	
4255	−0.011	−0.117	4322	+0.034		
4280	+0.051		4326		−0.088	$d_1 =$ +0.004
4308		0.119	4384		0.067	$d_2 =$ −0.096
4314	+0.004		4405	−0.013	0.073	$d_3 =$ −0.092
4319	−0.004		4415	−0.009	0.079	$d_4 =$ −0.108

1897—JULY 30.

A weak spectrogram, on which, however, the following measurements could be made :

λ 4405 $d_4 = +0.025$
λ 4415 $d_4 = +0.050$

1897—AUGUST 2.

λ	d_1	d_2	λ	d_1	d_2		
4261	—0.046	—0.127	4326		—0.125	$d_1 =$	+ 0.022
4272		0.135	4371	+0.014		$d_2 =$	—0.107
4295	+0.015		4384		0.091	$d_3 =$	— 0.085
4308	+0.026	0.155	4405	0.012	0.085	$d_4 =$	—0.110
4313	—0.005		4415	0.035	0.074		
4319	+0.027		4427	0.033			
4322	+0.028						

1897—AUGUST 13.

λ	d_1	d_2	λ	d_1	d_2		
4251	—0.237	+0.317	4371	0.350		$d_1 =$	+ 0.332
4308	0.310	0.347	4384		0.413	$d_2 =$	+ 0.379
4322	0.289		4405	0.363	0.424	$d_3 =$	+ 0.057
4326	0.340	0.376	4415	0.262 ?	0.419	$d_4 =$	+ 0.050
4370	0.349						

The displacements thus found are expressed in micrometer revolutions. To find the velocities in the line of sight use was made of the following table, which contains the values of a coefficient *K*, obtained by measuring solar spectrograms taken at different temperatures. Instead of the temperature, however, the argument is the linear distance between the lines λ 4308 and λ 4405, expressed in revolutions of the micrometer.

Argument	K	log. K	Argument	K	log. K
29.00	30.37	1.4825	29.80	29.57	1.4709
.10	.28	.4811	.90	.47	.4694
.20	.17	.4797	30.00	.37	.4679
.30	.07	.4783	.10	.27	.4665
.40	29.97	.4768	.20	.18	.4651
.50	.88	.4754	.30	.09	.4637
.60	.77	.4738	.40	.00	.4624
.70	.67	.4724	.50	28.90	.4609

For the displacement of the line $\lambda\,4405$, $\log K = 1.4975$.

The length of the interval $\lambda\,4308$—$\lambda\,4405$ on the spectrograms of the star was as follows:

July 10,	30.06	July 17,	30.10	July 26,	30.08
11,	.06	22,	.11	Aug. 2,	.09
12,	.07	25.1,	.05		
13,	.07	25.2,	.05		

Performing the reductions we have the following table.[1]

No.	Pulkowa mean time	Displacement	Observed motion	Reduction to Sun	Motion relative to Sun
	d h	r	km	km	km
1	July 10 12	−0.153	−33.3	+4.6	−28.7
2	11 12	−0.152	−33.0	+4.1	−28.9
3	12 13	−0.109	−23.7	+3.7	−20.0
4	13 12	−0.069	−15.0	+3.3	−11.7
5	17 12	−0.124	−26.9	+1.4	−25.5
6	21 12	−0.041	−9.1	−0.5	−9.6
7	22 12	+0.005	+1.1	−0.9	+0.2
8	25 11	−0.137	−29.8	−2.2	−32.0
9	25 12	−0.123	−26.8	−2.2	−29.0
10	26 11	−0.100	−21.7	−2.7	−24.4
11	30 12	+0.038	+8.9	−4.5	+4.4
12	Aug. 2 11	−0.098	−21.2	−5.9	−27.1
13	13 11	+0.054	+11.7	−10.7	+1.0

By means of the light ephemeris given in the *Annuaire du Bureau des Longitudes* we obtain the intervals between the epoch of minimum and the times of observation, as follows:

	Int.		Int.
July 10,	$2^d\ 14^h$	July 22,	$0^d\ 6^h$
11,	3 14	25,	3 6
12,	4 15	25,	3 7
13,	5 14	26,	4 8
17,	2 10	30,	1 2
21,	6 10	Aug. 2,	4 1
		13,	0 17

We can now draw the curve of velocities in the line of sight. Assuming that the period of revolution $= 7^d\ 4^h$ we find the following elements:

[1] In conformity to the practice of this JOURNAL, the German geographical miles used by the author have been reduced to kilometers.

Motion of the system $= -1.85^{\mathrm{gm}} = -13.7^{\mathrm{km}}$. Then[1]

$A = 16.3^{\mathrm{km}}$ $A + B = 32.6^{\mathrm{km}}$ $2\sqrt{A\,B} = 32.6^{\mathrm{km}}$

$B = 16.3^{\mathrm{km}}$ $A - B = 0.0^{\mathrm{km}}$

$z_1 = 77$ $z_2 + z_1 = -30$

$z_2 = -107$ $z_2 - z_1 = -184$

$u_1 = 90^\circ.0$, point for which velocity in line of sight $= 0$

$u_2 = 270^\circ.0$

$\omega = 90^\circ.0$, longitude of periastron

$e = 0.163$

$\left(\frac{dz}{dt}\right) = 00$

$T = +2^{\mathrm{d}}\ 0^{\mathrm{h}}$, time of periastron passage

$a \sin i = 1\ 382\ 000^{\mathrm{km}}$.

Inverted.

See δ 62 of Vol. 9.

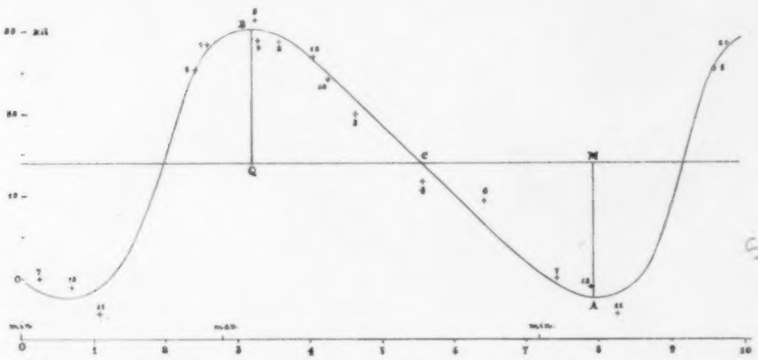


FIG. 1.

It will be seen that the times of minimum brightness and the times for which the velocity in the line of sight is zero do not coincide. For this reason the changes in the brightness of the star cannot be explained as the result of eclipses, and some other explanation must be sought. It is very remarkable that this is also true of the variable star δ Cephei. (See my researches on that subject in the *Bull. Acad. St Pétersbourg.*)[2]

[1] LEHMAN-FILHÉS, *A. N.* 3242.

[2] Also this JOURNAL, 1, 160–161, 1895.

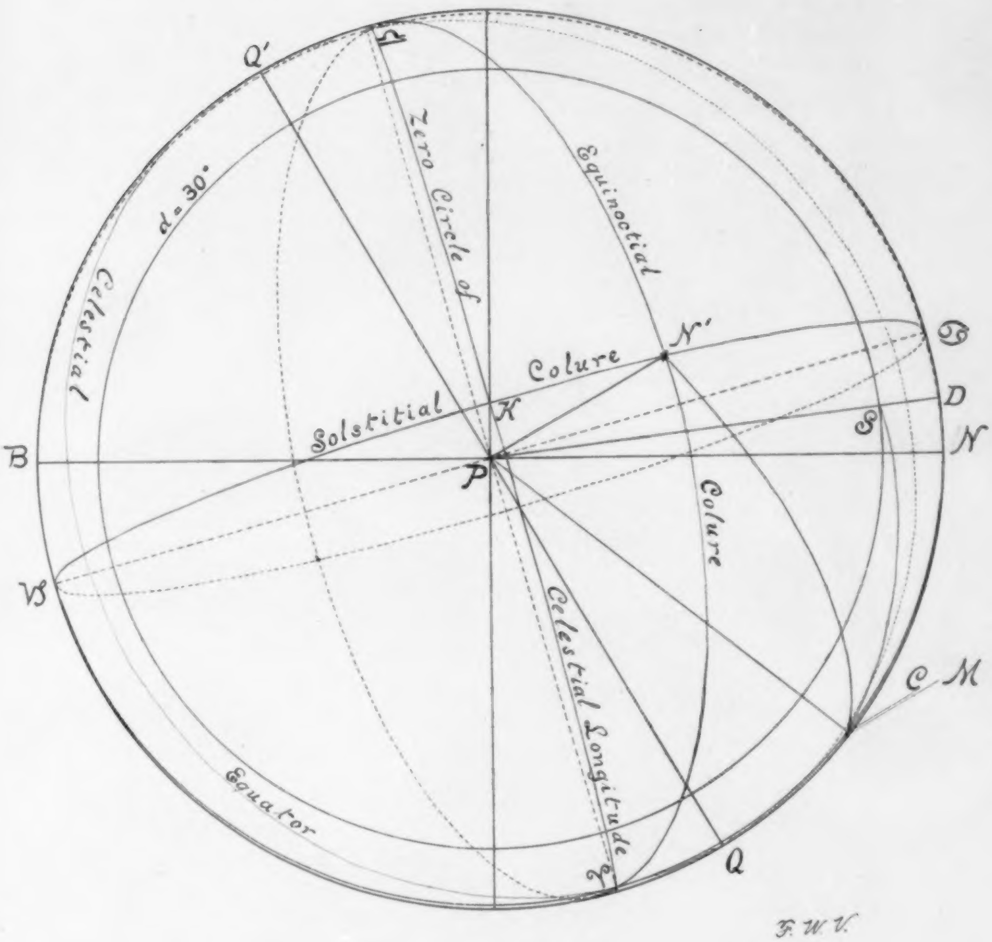
HELIOGRAPHIC POSITIONS. II.

By FRANK W. VERY.

IN my previous article, I have given the steps by which the radius and position-angle of a Sun-spot, referred to the center of the solar image, may be obtained and freed from error. We wish to know the positions as seen from the center of the Sun, and for the further transformation of the coördinates we again employ methods devised by Mr. Carrington. The subject is one not entirely devoid of pitfalls for the unwary, as I shall show first by a reference to the *Philosophical Transactions of the Royal Society of London* for 1869 (**159**, 1–110) in which is a memoir by De La Rue, Stewart, and Loewy, entitled: "Researches on Solar Physics. Heliographical Positions and Areas of Sun-spots observed with the Kew Photoheliograph during the years 1862 and 1863." A representation of some of the leading circles of the sphere is given in an illustration (Fig 10, *loc. cit.*)[1] which does not purport to be a true orthographic projection, but a diagrammatic construction, exaggerating the angles for the sake of clearness. It is, however, incorrect. The point in it, marked N', should be on a projection of the solstitial colure through E, the ecliptic pole, and not on a great circle through the Sun's pole (P) and the solstitial points; while C, the projection of the Earth's position on the celestial sphere, must necessarily be on the ecliptic trace, and not (as there given) on a projection of the Earth's equator far from the ecliptic. Besides this, the Earth's equator and the ecliptic must intersect, not on the outer bounding circle which represents the Sun's equator, but at inner points, marked ♈ and ♎ in the correct representation which is given here (so far as I know) for the first time; and in consequence of these errors, the line representing the Earth's equator has been incorrectly drawn in the figure cited. For these reasons, and in

[1] To be compared with Plate XXIII accompanying this article.

PLATE XXIII.



F. W. V.

order to show the true relations, I have substituted an exact, although composite, projection.

In Plate XXIII there is given a projection of the celestial sphere upon the plane of the Sun's equator. The poles of the Earth, Sun and ecliptic, the position of the Earth in its orbit, and various other important lines and points, are first projected radially upon the celestial sphere, and the latter is then projected orthographically upon the plane of its solar equinoctial circle. The Earth's equator intersects the Sun's equator at the points Q, Q', and the ecliptic plane meets the solar equatorial plane in the line NB.

An examination of the correct representation will also show that in the position chosen in another figure given by De La Rue,[1]

EXPLANATION OF PLATE XXIII.

Plate XXIII is an orthographic projection of the celestial sphere on the plane of the Sun's equator. The Earth is supposed to be projected in C; and S is the projection of a Sun-spot.

$N' C =$ celestia meridian through C.
$P M =$ solar meridian through C.
$d = S D =$ heliographic latitude of Sun-spot.
$\rho = S C =$ heliographic angle of Sun-spot from Earth.
$D = M C =$ heliographic latitude of the Earth.
$\chi = S C P =$ terrestrial position-angle of the Sun-spot from the Sun's north pole
$L = N M =$ heliographic longitude of the Earth from the Sun's ascending ecliptic node (N), read in the usual direction and therefore greater than 180° in the figure.
$l = N D =$ heliographic longitude of the Sun-spot from the Sun's node.
$K =$ projection of north pole of ecliptic.
$P =$ projection of north pole of Sun.
$N' =$ projection of north pole of Earth.
B ♈ $C N$ (inner line) visible half of ecliptic.
$N Q' Q M$ (outer bounding circle) $=$ solar equator in plane of projection.
$Q =$ ascending node of Sun's equator on Earth's equator.
$Q' =$ descending node of same. The invisible half of Earth's equator, as seen from the direction of the Sun's north polar axis produced, is shown dotted.
Arc ♈ $N = 74° 22'$ (year 1900 A.D.)
Arc $N Q = 59° 54'$
Arc $K P = 7° 15'$
Arc $K N' = 23° 27'$
Arc $P N' = 26° 17'$

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[1] Fig. 9, *loc. cit.*, copied, however, without alteration from a figure given by Carrington. Compare with Fig. 4, Plate XXIV, accompanying this article.

N' instead of being at the left should be at the right of P,[1] which should incline forwards towards C, the center of the solar disk, by an arc which is the foreshortened projection of CM, the semiminor axis of the equatorial ellipse. The node (N) should be at the extreme right. The opening of the elliptic projection of the Sun's equator is much exaggerated in this figure, and also in several published by Secchi, Young, and others. In fact the only exact representations of this feature which I have seen, are those of Sir Robert S. Ball in his *Story of the Sun*.

The symbols used by De La Rue, Stewart, and Loewy in their treatment of the problem of heliographic positions, are in the main the same as those of Carrington,[2] and (with trifling modifications) shall now be gathered together, for convenience of reference.

$\odot$ = celestial longitude of Sun.

N = celestial longitude of the ascending node of the Sun's equator.
= $73^\circ\ 40' +$ precession from 1850.

I = inclination of Sun's equator to ecliptic.
= $7^\circ\ 15'$ (Carrington's elements).

ω = inclination of Earth's equator to ecliptic.

R = solar radius of drawing or photograph (in inches for example).

r = measured distance of a Sun-spot from the center of the Sun-picture (same unit).

r' = same corrected for distortion.

R'' = tabular value of Sun's semidiameter for the given date (from Ephemeris).

ρ' = measured distance of a Sun-spot from the center of the drawing in terms of the tabular semidiameter, R''

[1] The direction in which heliographic longitude is said to be reckoned in this figure shows that it cannot be a perverted (right for left) image, and if it represented a position six months later, being then of an April date, instead of September, the points N and B would have to change places.

[2] R. C. Carrington, *M. N.*, **15**, 175, 1855.

ρ = heliographic (or heliocentric) angle of Sun-spot from the Earth's position.

G = angle at the Sun's center between the pole of the Earth and the pole of the ecliptic, as orthographically projected on the Sun-picture (positive when the projection of the Earth's north pole is seen east of the projection of the north pole of the ecliptic).

H = angle at the Sun's center between the pole of the Sun and the pole of the ecliptic, orthographically projected on the Sun-picture (positive when the projection of the north pole of the ecliptic is seen east of the Sun's north pole).

L = nodal heliographic longitude of the Earth, or longitude of the Earth measured along the solar equator from the ascending node of the Sun's equator on the ecliptic

D = heliographic latitude of the Earth.

P = position-angle of Sun-spot, reckoned from terrestrial north, through east (measured on Sun-drawing or photograph by a protractor, or originally at the telescope by the position-filar micrometer).

$\chi = P + G + H$.

d = heliographic latitude of Sun-spot.

l = nodal heliographic longitude of Sun-spot, or longitude measured along the Sun's equator from the Sun's node as origin.

$L-l$ = heliographic longitude of Sun-spot from central meridian.

l' = heliographic longitude of adopted solar prime meridian from the Sun's node.

$L-l'$ = heliographic longitude of the center of the solar disk from the solar prime meridian.

$l-l'$ = heliographic longitude of Sun-spot from the solar prime meridian.

T = the fraction of a revolution executed by the prime meridian at a given date, expressed usually in time.

The following ten equations are sufficient for the computatation of heliographic position :

(1) $\tan G = \tan \omega \cos \odot.$

(2) $\tan H = \tan I \cos (\odot - N).$

(3) $\tan L = \cos I \tan (\odot - N).$

(4) $\sin D = \sin I \sin (\odot - N).$

(5) $\rho' = \frac{r'}{R} (R'').$

(6) $\rho = \sin^{-1} \frac{r'}{R} - \rho'.$

(7) $\sin d = \cos \rho \sin D + \sin \rho \cos D \cos \chi.$

(8) $\sin (L - l) = \sin \chi \sin \rho \sec d.$

(9) $T = \frac{t}{25.38} - m.$

T being the remainder left after dividing the interval (t) from the epoch (or number of days between 1854.0, civil reckoning, and the date of observation) by 25.38 days, the adopted period of the Sun's sidereal rotation. The number of complete sidereal rotations of the prime meridian, which have been executed since the epoch is denoted by m.

(10) $l' = T \times \frac{360^\circ}{25.38} = 14^\circ.1844 \times T.$

These formulæ have been derived by the method of Mr. Carrington, "who by introducing tabulated auxiliary values has condensed the two steps necessary for passing from the ecliptical longitude and latitude to the heliographical into one."

We pass next to the derivation of these formulæ. In Fig. 1, Plate XXIV, AB representing the trace of a plane parallel to the plane of projection of a Sun-picture, and ASB the solar hemisphere presented towards the Earth, it is evident that the measured radial distance of the spot (S) from the center of the picture is $O'S'$ which is greater than OS, the true distance of the spot from the central line of sight ($O'O$). The measured distance must therefore be reduced in order to get OS, from which the heliocentric angle ρ may be obtained. From the figure,

PLATE XXIV.

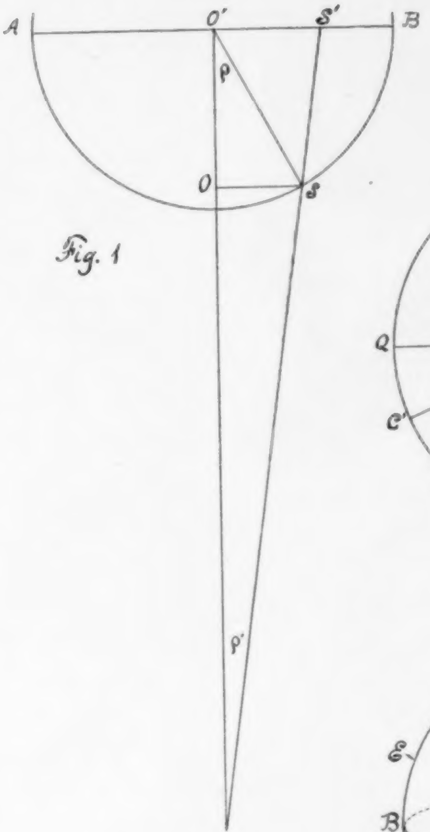
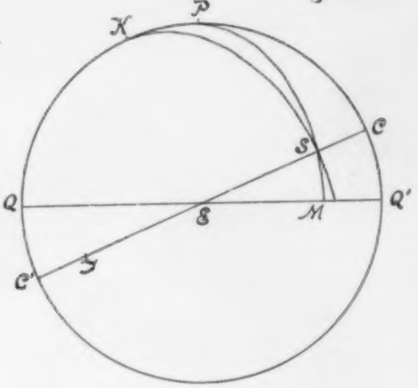


Fig. 1

Fig. 2



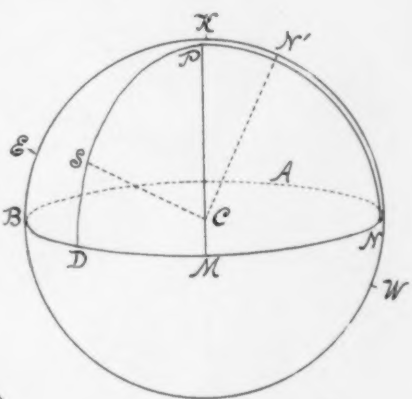


Fig. 4

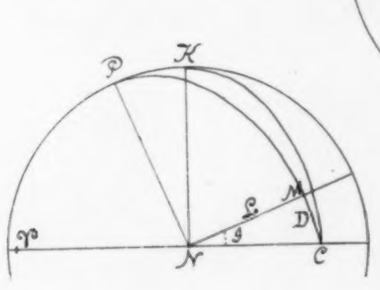


Fig. 3

$$\rho' = \frac{O'S'}{O'B}(R'') = \frac{r}{R}(R''),$$

approximately, and

$$\frac{r}{R} = \frac{O'S'}{O'B} = \frac{O'S'}{O'S} = \sin O'SS' = \sin(\rho + \rho'),$$

approximately,[1] or

$$\rho + \rho' = \sin^{-1}\frac{r}{R};$$

hence

$$\rho = \sin^{-1}\frac{r}{R} - \rho'.$$

In Fig. 2, Plate XXIV, "let $C'EC$ represent the ecliptic, $Q'EQ$ the celestial equator, and K and P the poles of these circles. Then if S is the position of the Sun, ES will be its longitude $=$ $\odot$, and the angle $SEM = \omega =$ the inclination of the ecliptic. Now if the angle $KSP = G$ represents the inclination of two planes passing through the line joining the centers of the Sun and Earth, and the poles of the Earth and ecliptic respectively, then in the triangle ESM, right angled at M, we shall have :

$$\cos ES = \cot SEM \cot ESM,$$

or

$$\cos \odot = \cot \omega \tan G,$$

whence

$$\tan G = \tan \omega \cos \odot \text{ ."}$$ [2]

"Similarly, if H be the inclination of two planes passing through the line joining the centers of the Sun and Earth and the poles of the Sun and ecliptic respectively, we should obtain by a corresponding figure :

$$\tan H = \tan I \cos(\odot - N),$$

where I is the inclination of the Sun's equator to the ecliptic, and N the longitude of the ascending node." (De La Rue, Stewart, and Loewy, *Phil. Trans.*, **159**, 11, 1869.)

[1] More exactly, $\tan \rho' = \frac{r}{R}\tan(R'')$, and $\frac{r}{R} = \frac{\sin \rho' \cos \rho + \cos \rho' \sin \rho}{\cos \rho'}$ $= \frac{\sin(\rho + \rho')}{\cos \rho'}$. But $\cos \rho'$ is only a trifle less than unity.

[2] Fig. 2, Plate XXIV, is a view of the celestial sphere from the outside. The line of sight from the Earth to the Sun follows the direction TES, the position of the Earth being at T on the opposite side of the sphere from S. E is the vernal equinox on the nearer side of the sphere. G, then, according to definition, will be positive in the present instance.

Attention must be paid to the signs of G and H. Cos $\odot$ is positive in the first and fourth quadrants, and negative in the second and third. For the epoch 1900 A.D.,

$\cos(\odot - N)$ is positive from $\odot = 344°22'$ to $\odot = 164°22'$
" " negative " $\odot = 164°22'$ to $\odot = 344°22'$.

Hence from

$\odot = 0°$ to $90°$, G is positive, H is positive,
$90°$ to $164°22'$, G is negative, H is positive,
$164°22'$ to $270°$, G is negative, H is negative,
$270°$ to $344°22'$, G is positive, H is negative,
$344°22'$ to $360°$, G is positive, H is positive.

The heliographic coördinates of the center are derived in the following way: In Fig. 3, Plate XXIV, P is the pole of the Sun, K the pole of the ecliptic (exaggerating the angle between them for the sake of clearness). C is the position of the Earth upon the celestial sphere, ΥC being the Earth's celestial longitude, or $180° + \odot$. N is the position of the ascending node of the Sun's equator on the ecliptic. In the final equations, the letter N also stands as a symbol for the arc ΥN.

NC = a part of the ecliptic $= (\odot - N) - 180°$.
$L = NM$ = nodal heliographic longitude of the Earth.
[1] $D = MC$ = heliographic latitude of the Earth.
$I = MNC$ = inclination of the solar equator to the ecliptic.

From the triangle MCN, right-angled at M, we have

$$\tan L = \cos I \tan(\odot - N)$$
$$\sin D = \sin I \sin(\odot - N).$$

The signs of the functions of $(\odot - N)$ for the epoch 1900 A.D. are:

$\tan(\odot - N)$ positive from $\odot = 74°22'$ to $\odot = 164°22'$
" negative from $\odot = 164°22'$ to $\odot = 254°22'$
" positive from $\odot = 354°22'$ to $\odot = 344°22'$
" negative from $\odot = 344°22'$ to $\odot = 74°22'$
$\sin(\odot - N)$ positive from $\odot = 74°22'$ to $\odot = 254°22'$
" negative from $\odot = 254°22'$ to $\odot = 74°22'$.

[1] In the present case D is negative, and the expression involving $(\odot - N)$ must be interpreted accordingly.

For the transformation of celestial into nodal heliographic coördinates, we have these equations :

$$\tan a = \sin \lambda \cot \beta, \tag{11}$$

$$\tan L' = \frac{\sin (I + a)}{\sin a} \tan \lambda, \tag{12}$$

$$\sin D' = \frac{\cos (I + a)}{\cos a} \sin \beta. \tag{13}$$

where a is an auxiliary arc, λ stands for celestial longitude, and β for celestial latitude (heliocentric), and L' and D' are the corresponding quantities in the solar arcs. These formulæ are needed for comparing the positions of Sun-spots with those of planets or comets in testing the possible connection, or at least coincidence of their conjunctions, etc. From these formulæ we may also deduce the nodal heliographic positions of the celestial pole, but more simply as follows. Since the angle between the solar and terrestrial rotation-axes is the same as that between their equators, the projection of the Sun's north pole on the celestial sphere is $26° \; 17'$[1] from the north celestial pole, or in declination $63° \; 43'$. Its right ascension is $90°$ behind the point Q, the ascending node of the Sun's equator on that of the Earth, or $74° \; 05'$ behind the vernal equinox, that is, the right ascension of the Sun's north pole is $285° \; 55' = 19^h \; 3^m \; 40^s$. In like manner, the nodal heliographic coördinates of the Earth's north pole are :

$$D_N = 90° - 26° \; 17' = 63° \; 43'$$

[2] $$L_N = 90° - 59° \; 54' = 30° \; 6' \qquad \text{(Epoch 1900).}$$

In what precedes, we have considered what is virtually a projection of the celestial sphere inwards upon the Sun-sphere, which in turn is viewed from without, and must not be confounded with a star-map which is supposed to be projected outwards upon the inner concave surface of the celestial sphere, or

[1] In Plate XXIII, the angle between the solar and the terrestrial equators is $Q = 180° - ♈ Q N$, and $\frac{1}{2} \cot ♈ Q N = \frac{\sin \frac{1}{2} (Q N + ♈ Q)}{\sin \frac{1}{2} (Q N - ♈ Q)} \times \tan \frac{1}{2} (\omega - I)$.

[2] The arc $59° \; 54'$ is the amount by which the intersection of the solar and terrestrial equators precedes the Sun's node.

on some tangent plane, cone, or cylinder, and which is viewed from the inside. The former is an artificial or composite conception. If the point of view is in the prolongation of the Sun's axis of rotation, and at an infinite distance, we get the appearance shown in Plate XXIII. As seen from the Earth, however, the appearance of the Sun and its chief circles is as represented in the twelve diagrams (one for each month) in Ball's *Story of the Sun* (Fig. 39, p. 154). Both kinds of figures are needed to complete the conception of the relations between the diverse planes and nodes. Plate XXIII is of especial use as a test of the student's comprehension of the subject. From the scarcity of accurate representations of the solar zones in their varying presentation, one might infer that these relations are not often studied even by professional astronomers. The subject, however, is not inherently difficult, and with the help of the diagrams mentioned, and a little exercise of the geometrical imagination, all of the statements made here should be easily verified.

A projection-drawing of the Sun cannot be viewed from behind, like a photographic transparency, without subjection to some modifying process. In order to see the parts in their true relation, the drawing may be inverted on an illuminated glass table, and traced through on the back side of the paper. If a concave eyepiece lens (Galilean telescope) has been used in getting the projection, the drawing (held in its original position) should be rotated about its east and west diameter, when the reverse will be correctly oriented; but if a convex eye-lens has been employed in projection, the drawing, previously held with its north point uppermost, must be rotated about a vertical diameter to give the direct view as seen from the back.

We come now to the final object of our labor—the reproduction of important heliographic circles and points upon the face of a Sun-picture, and the quantitative determination of their positions. Every Sun-picture should have its east and west line carefully determined, and the orientation correctly labeled. The eyepiece used in projection, and the date and time of the

picture, should also be added. If the whole Sun has been drawn, the diameter of the circular margin, in conjunction with the angular diameter of the Sun given in the ephemeris, will fix the scale; but if only a part of the solar surface has been depicted, a series of transits of the Sun's limb, or of a sharp spot, between spaced lines on the drawing should be chronographically timed, giving the means of finding the scale.

In plotting the fundamental data upon a Sun-picture, the projection of the pole of the ecliptic (angle G) is first laid off from the north point on the limiting circle, and a similar construction from the east point will give a marginal point which, joined to the center by a straight line, shows the direction of the Sun's annual apparent motion.

Next, laying off an arc of $7\frac{1}{4}$ degrees on either side of the ecliptic pole, its chord will be the path in which the Sun's pole travels, and the angle H, laid off by the protractor on this chord, fixes the position of the Sun's pole and axis. The major axis of the solar equatorial ellipse may be drawn through the center at right angles to the polar axis. Drawing a chord at right angles to the polar axis through the projection of the Sun's pole, this chord is also the minor axis of the equatorial ellipse.[1] With these data the ellipse is readily constructed. The rear half is preferably dotted. The nodal heliographic longitude of the center being that of the Earth (L), the heliographic longitude of the solar prime meridian from the center of the disk is $L–l'$, and this angle being computed in the manner to be described in the concluding article may be laid off on the margin from the projection of the Sun's polar axis. The marginal point thus obtained is to be projected on the equatorial ellipse by a line parallel to the polar axis, giving the projection of the origin of heliographic coördinates. The Sun's node will always be at the intersection of the equatorial ellipse and the ecliptic trace.

[1] The reasons for these procedures will be evident to all who are familiar with descriptive geometry. Mr. R. A. Proctor has explained the method of construction as applied to a special case of planetary presentation in *Old and New Astronomy* (p. 456), and has given the mathematical principles involved in *M. N.*, **38**, 320, 1878.

These lines and points will ordinarily be sufficient to insure a correct conception of the solar presentation.[1]

All solar arcs will ordinarily be reckoned heliocentrically but for precision this, or an equivalent term, must be included in their nomenclature. In analogy with the term geographic longitude, it is customary to use the expression *heliographic longitude* to denote longitude reckoned heliocentrically along the Sun's equator from an assumed solar prime meridian. For example, we have *heliographic longitude from Carrington's prime meridian* which coincided with the Sun's node at the epoch, Greenwich mean midnight between December 31, 1853 and January 1, 1854, and which is arbitrarily assumed to have a true rotation period of 25.38 days, this being approximately the sidereal rotation period of an average Sun-spot. Again, we have *heliographic longitude from Bigelow's prime meridian* which was central on June 12.22, 1887, and is assumed to have a synodic rotation period of 26.67928 days, agreeing with a supposed periodicity of terrestrial magnetism attributed to solar influence, and possibly representing

[1]Comparison with a diagram similar to Plate XXIII, or with a solar globe, orienting the figure, or the globe, according to the place of the Earth in its orbit, will be found useful as a check on the accuracy of these constructions. In making such a diagram or globe, the following points are the principal ones to be considered. The solar equator being drawn, the poles of the various systems of coördinates follow, according to the precept already given. (Ante p. 408.)

On Plate XXIII, QMN being an arc of the solar equator, and $♈CN$ an arc of the great circle in which the ecliptic plane intersects the surface of the Sun-sphere, we have :

Point $♈$ = the ascending node of the ecliptic, or to be precise, this point is the intersection at the Sun's surface of the plane of the Earth's orbit with a plane through the Sun's center parallel to the Earth's equator. The direction of $♈$ from the Sun's center is also that of the Earth at the autumnal equinox. The angle $N♈Q = \omega = 23° 27'$.

Point Q = the ascending node of the Sun's equator on a plane through the Sun's center parallel to the Earth's equator. The angle $Q = 180° - ♈QN$ = inclination of Sun's equator to Earth's equator $= 26° 17'$ for the epoch 1900 A. D.

Point N = the ascending node of the Sun's equator on the ecliptic. The angle $♈NQ = I = 7° 15'$.

The arc $♈Q$ = the right ascension of point $Q = 15° 55' = 1^h 3^m 40^s$. The arc QMN = the nodal heliographic longitude of point Q, or reckoned in the usual direction, $l_Q = 300° 6'$.

The arc $♈N$ = the celestial longitude of the Sun's node, for which has been adopted the symbol $N = 74° 22'$, for 1900 A. D.

the rotation of a fairly coherent and unsymmetrically magnetic solar nucleus in a true rotation period of about 24.86 days.[1]

Nodal heliographic longitude, or heliographic longitude *from the Sun's node*, is longitude reckoned heliocentrically along the Sun's equator from the Sun's ascending node on the ecliptic. For this kind of longitude the symbols L, or l, have been used in this article.

[1] FRANK H. BIGELOW, *Monthly Weather Review*, issued by the United States Weather Bureau, for March 1895, p. 91.

ON THE PRESENCE OF CARBON IN THE CHROMOSPHERE.

By George E. Hale.

In an article on the Yerkes Observatory, published in 1892,[1] I called attention to the advantages which the forty-inch telescope seemed to offer for solar investigations, and outlined a general plan of work in this field. The results of the photographic observations of the ultra-violet spectrum of the chromosphere, then in progress at the Kenwood Observatory, convinced me that certain advances in our knowledge of the spectrum of the Sun's limb might reasonably be expected to follow from work with a large solar image.

In September of the present year, when it became possible for the first time to undertake spectroscopic observations with the large telescope, I attached to the instrument the solar spectroscope which formerly belonged to the Kenwood Observatory, where it had been used with the 12-inch refractor. The collimator and observing telescope of this spectroscope are each of $3\frac{1}{4}$ inches aperture and $42\frac{1}{2}$ inches focal length. As the ratio of aperture to focal length in the forty-inch telescope is $\frac{1}{19}$, the effective aperture of the solar spectroscope is only about 2.2 inches. The grating has 14,438 lines to the inch on a ruled surface $1\frac{15}{16}$ by $3\frac{3}{16}$ inches. The greater part of the observations were made in the second order spectrum, though the third was sometimes employed.

On September 14, when the first observations of the chromospheric spectrum were made with these instruments, the color curve of the forty-inch objective had not been determined. In spite of the consequent uncertainty regarding the focus for dffferent parts of the spectrum, many bright lines were seen at each point of the limb examined, though there were no evidences of eruptive activity. On September 16 similar results were obtained. On September 18 some twenty-five bright

[1] *Astronomy and Astrophysics*, XI, 790, 1892.

lines were seen in the region $\lambda 5198$–5363. The wave-lengths were determined by comparison with Rowland's map, and it was found that several of Young's low-frequency lines had been observed, while two or three of the lines were apparently new. In this case, as in the others, there was no evidence of an eruption. On September 25 the color curve was roughly determined by means of observations of the Sun's limb with a radial slit, and the driving-clock was adjusted for solar rate. Over thirty bright lines were seen between C and D, and one or two new lines were found. On September 29 the seeing was so good that the form of the chromosphere could be well seen with a power of about 700. With a narrow slit an extraordinary number of bright lines were visible. In the region just above *b* the lines were closely grouped together, and seemed to form a fluting. Suspecting the presence of the green carbon band, I carefully determined the position of the head of the fluting in the solar spectrum. The wave-length thus obtained corresponded as accurately as the precision of the observation allowed with the known wave-length of the red edge of the carbon fluting. The wave-lengths of the individual dark lines of the fluting which occur in the solar spectrum are given in Rowland's Table of Solar Spectrum Wave-lengths. Using a narrow slit, placed nearly tangential to the Sun's limb, which slightly overlapped it, the dark lines of the disk were seen to become bright where the slit crossed the chromosphere. In another observation the procedure was slightly different. The slit was set on the Sun's disk near the limb, where the dark lines ascribed by Rowland to carbon could be seen. Fixing his attention on one of these lines, the observer, by pressing against the tube, moved the telescope sufficiently to bring the slit into the chromosphere. Several lines examined in this way were found to be reversed in the chromosphere. The head of the fluting was also reversed in the same way. M. Deslandres, who was visiting the Observatory at the time, kindly examined the chromospheric spectrum, and had no difficulty in seeing the new lines. They have since been observed on several occasions by Professor Runge, Professor Keeler, and others. Although I intend to make further com-

parisons of carbon and chromosphere lines, I consider the observations already made sufficient to demonstrate the presence of carbon in the chromosphere.

As the lines were on each occasion seen at every point of the limb examined, I am inclined to think that they form a part of the normal spectrum of the undisturbed chromosphere, and that they will be visible with the forty-inch telescope whenever the atmospheric conditions are good. The layer of carbon vapor is thin, and it is consequently necessary to have a large image and good seeing in order to render the lines visible.

After the observations had been made, I found that Professor Young had recorded in his partial revision of the chromospheric spectrum a line at $\lambda 5165.2$, of frequency 3, intensity 5, element C ?, with the following remarks: "High-level line, unmistakable on the photographs; dark line extremely faint, if visible at all; agrees exactly with C marked upon Rowland's map." The photographs referred to were taken on June 20, 1893, by Professor Reed, "during an energetic outburst of chromospheric activity." Although the wave-length given by Rowland for the head of the fluting differs about a quarter of a tenth-meter from the value given by Professor Young, there can be little doubt that the head of the carbon band was really photographed. As the distance between b_1 and b_4 on the negatives is only about a tenth of an inch, such an error might easily have been made in estimating the position of a line. Through the kindness of Professor Young, I have had an opportunity to examine two of these plates. The bright line just referred to is well shown, but, as one might expect from the conditions in which the photographs were made, there appears to be no trace of the rest of the fluting on any of the negatives.

After consulting Professor Young, who declares himself in full sympathy with the plan, I have decided to undertake a revision of the chromospheric spectrum with the forty-inch telescope. The excellent seeing enjoyed here during the summer months should greatly facilitate the work.

YERKES OBSERVATORY,
October 1897.

Minor Contributions and Notes.

PROCEEDINGS OF THE CONFERENCES HELD AT THE YERKES OBSERVATORY, OCTOBER 18–21, 1897.

THE following synopses of the papers read at the astronomical and astrophysical conferences held at the Yerkes Observatory in connection with the dedication, have been prepared by the authors. In some cases only the title is given, on account of the author's desire to publish the complete paper in the ASTROPHYSICAL JOURNAL or elsewhere. The order of the papers is that in which they were read at the conferences.

ON THE MODE OF PRINTING MAPS OF SPECTRA AND TABLES OF WAVE-LENGTHS.

My opinion with regard to the mode of printing maps of spectra and tables of wave-lengths agrees very nearly with that expressed by Professor Keeler in the August number of this JOURNAL. It does not seem to me to be a matter of very great importance what decision is arrived at, but in whatever way the question is settled, all spectroscopists should conform to a uniform practice, even if it involves a little personal inconvenience at first. In making the few remarks which have occurred to me in connection with this matter I will take up the two questions separately.

1. *Mode of printing maps.*— What has determined the mode of printing maps? No doubt the particular construction of the spectroscopes employed by different observers. Fraunhofer must have had his spectroscope constructed so that he saw the red to the left, while Kirchhoff placed his prisms so that he saw the colors of the spectrum in the reverse direction. Many students first become acquainted with the appearance of the spectrum by means of the plates copied from Bunsen and Kirchhoff's first paper, in which the red is placed on the left; and hence they cannot picture to themselves the spectrum in any other way. Small spectroscopes are also, I believe, almost invariably made now so as to place the red on the left. The only reason for this that I can see, is that the observer while looking at the spectroscope

ought to be able to handle the slit and flame or spark in front of the slit, and it is generally more convenient for him to use his right hand for the purpose. With single-prism spectroscopes this would render it necessary to construct them so that the red is on the left. But that is not an important matter, for physicists ought to be able to open or close the slit with the left hand. It would be well, however, if the practice of placing the red is adhered to, to get instrument makers to construct their spectroscopes accordingly, and architects to build their lecture rooms with the lantern on the right and the screen on the left. There may be some natural tendency in human beings which would favor one direction more than another. The way to find this out would be to place a small direct vision spectroscope in the hands of scientifically uneducated persons and to observe which way they hold it. My own experience would lead me to think that they would place the slit horizontal, so that the red would be either top or bottom; and there may even be something to be argued in favor of that practice. I only bring out these points to show that one might discuss the question indefinitely, and if one could start fresh from the beginning I do not know whether the balance of unimportant considerations would not turn in favor of having the red on the left. But Rowland's map is constructed with the red on the right, and this fact outweighs, in my opinion, all other considerations. In the majority of spectroscopic investigations of the present day Rowland's map has to be used, and it would be unbearable always to have to invert the direction. I should be sorry, therefore, if the present practice of the ASTROPHYSICAL JOURNAL were altered. Any one, of course, is at liberty to print a scale with inverted numbers at the bottom of a map, so that by turning the page around the smaller wave-lengths appear on the right. The question of series of lines I will discuss presently.

2. *Mode of printing tables.*— Here also most arguments which have been used in favor of one practice rather than another do not seem to me of very great weight. Wave-frequencies are quantities as important as wave-numbers, and if the latter succeed each other according to increasing figures, the former do so in the opposite way. But here the question of series has to be taken into consideration. It certainly seems more natural to print a series of lines which gradually become fainter so that the strongest should appear at the top. I would for this reason favor the reversal of the practice recommended by the Editorial Board. It has been argued that in printing maps the first and strong-

est lines of the series, and hence the red end, should be on the left, but I do not see that this is a matter of paramount importance. To my mind a series looks as well with the tail on the left as the other way around; with the present practice of the JOURNAL no doubt the characteristic numbers of the lines in a series would increase from right to left, but I do not know that this is unnatural. A great many nations write from right to left and if one were to count a row of soldiers it would be as easy to begin at one end as at the other. Those who are accustomed to consider a positive rotation as one opposite to that of the hands of a watch would, I believe, not find it unnatural when the first impulse is overcome to look at a series as beginning on the right hand side and tailing off on the left. Counting things from right to left seems to me to belong to a more advanced civilization than our present practice, which is the consequence of the apparent rotation of the Sun around the Earth. As soon as we realize that it is the Earth that rotates, the left handed way of counting things becomes the more natural one. Giving all due weight to the fact that Kayser and Runge's practice is to have the head of a series on the left, I believe that Rowland's map must settle the question as to the position of the red end, while in the matter of printing tables the increasing importance of Kayser and Runge's series renders it advisable to reconsider and probably to reverse the present mode followed by the JOURNAL.

While I am writing on these subjects I should like to mention two matters which might deserve the attention of the Board of Editors. One is the position of the decimal point in tables of wave-lengths or wave-numbers. In tables of the former, the practice of giving four figures in front of the decimal point is almost universally adopted, and should, in my opinion, be adhered to. But no general system is followed for wave-frequencies, and there seems to me to be a great advantage, chiefly as a help to the memory, if the number given should always be the number of wave-lengths in the centimeter. This would give five figures, the wave-number for green light, *e. g.*, being 20000.

The other question refers to the notation for the intensity of light. I do not know whether it will be possible at the present stage of science to come to a definite agreement, owing to the difficulty of using the the same system for two such very different things as the solar spectrum and a spark spectrum. As a first step, however, I should like to urge that the higher intensities, whatever the scale, should always be denoted by the higher numbers. This is the practice adopted by the

majority of physicists, and it is a matter of some inconvenience to compare together the results of two researches, in one of which the number one denotes the greatest intensity, while in the other the same number stands for the weakest line. A scale reaching from one to ten, using decimal points if necessary, might perhaps commend itself, but personally I am willing to adopt any practice which may be decided upon.

ARTHUR SCHUSTER.

SPECTROSCOPIC NOTES.

By Sir William and Lady Huggins. (Published in the ASTROPHYSICAL JOURNAL, November 1897.)

THE VARIABLE STAR WORK OF THE HARVARD OBSERVATORY.

Professor Edward C. Pickering described the studies of variable stars in progress at the Harvard College Observatory. Variables of long period have been observed for many years throughout their variations, at minimum as well as at maximum. A sequence of comparison stars is selected for each, the variable is compared by Argelander's method, and all the results reduced to a uniform scale, that of the meridian photometer. Short period variables are measured with the meridian photometer and with a polarizing photometer attached to the large telescope. Smooth light curves are thus obtained. The variable stars, S S Cygni and U Geminorum, form a peculiar class. The first of these stars was observed on about two hundred nights. Photometric observations of it were made extending over the whole of one night during its rapid increase. Many thousand observations have been made of the Algol stars, especially of U Cephei and W Delphini, the most accurate timekeepers we have outside of the solar system.

STUDIES OF THE ELECTRIC ARC.

Professor Crew described a method of studying the electric arc which had been devised by himself and Mr. O. H. Basquin.

By working the arc in a hood filled with a gas which has no chemical action upon the electrodes, they avoid any luminosity which might be called a "chemical effect."

By the use of a rapidly rotating occulting screen, they examine the arc immediately after the current has been cut off, and thus avoid any luminosity which might be called an "electrical effect."

By the use of an alternating current, interrupted at the moment when the current-curve crosses the axis of X, they avoid "self-induction effects." In this manner the "purely thermal effects" are isolated.

It is found, however, that when the current is shut off different parts of the arc persist for different lengths of time. A spectroscopic examination of the different parts of the arc, and of arcs in different gases, is now in progress.

RESEARCH WORK AT THE WASHBURN OBSERVATORY. STELLAR PARALLAX, THE LUNAR ATMOSPHERE, THE OCULAR HELIOMETER.

The following summary of a paper presented to the astronomical conferences at the Yerkes Observatory is limited to two of the lines of research now in progress at the Washburn Observatory, the one by Mr. A. S. Flint, being an extensive series of determinations of stellar parallax made with the Repsold meridian circle used as a transit instrument in accordance with the principles outlined by Kapteyn (*Leyden Annalen* Bd. VII), the other, of very much less extent, being an investigation by the Director of the Observatory of the limits of density of an assumed lunar atmosphere whose existence is affirmed by many selenographers. In connection with the latter subject there was exhibited at the Williams Bay conferences a Steinheil ocular heliometer obtained for use in this investigation, but which in its present form has proved unsatisfactory because certain conditions which theory indicates as essential in such an instrument were not observed in its construction.

A brief notice of this type of micrometer has been given by Gill (*Encyclopædia Britannica*, article "Micrometer,") who condemns it as a failure; and a much more complete account by von Konkoly (*Centralzeitung für Optik und Mechanik*, July 1885), who assigns it the first rank among all known forms of double image micrometer. The writer of the present lines cannot agree entirely with either of these critics, but regards the instrument as possessing good points which at present are rendered in great part nugatory by theoretical defects of construction whose exposition lies beyond the scope of the present article.

The determination of relative parallaxes through observed differences of right ascension contains nothing novel in principle, but the method does not appear to have been applied systematically and successfully save by Kapteyn and in the work here to be outlined. The observing programme contained about a hundred stars chosen for the most part with reference to large proper motion and intended to com-

prise every star within 120° of the north pole whose proper motion exceeds one second of arc of a great circle. A certain number of these stars were, however, dropped from the list as being too faint for the very modest aperture, 122^{mm}, of the instrument, and their places, together with other lacunæ, were filled with other stars, usually interesting binaries or bright stars whose parallaxes elsewhere determined may serve as a control upon the general accuracy attained.

A normal observation consists in recording chronographically the times of transit over 25 threads of the star in question and two comparison stars so chosen that the star under investigation shall as nearly as may be bisect the arc joining them. It was in most cases feasible to select comparison stars which had not previously been employed for parallax determinations, but in some few cases, *e. g.*, Sirius and 61 Cygni, this was not done and could not be done without an undue sacrifice of other conditions. All of the stars observed were reduced to an approximate equality of brightness by the interposition of wire gauze screens immediately in front of the objective. An elevated track attached to the walls of the observing room supported these screens and permitted their convenient adjustment without allowing any part of the apparatus to come into contact with the telescope or its supports.

The parallax observations were commenced in October 1893, and terminated in August 1896, and the very laborious reductions are now sufficiently advanced to furnish the following results, each of which has been derived from a least squares solution involving in addition to the parallax a correction to the assumed relative star places and proper motions.

Star	Mag.	R. A.	Dec.	P. M.	Observed Parallax	Other Determinations
		h m	° ′	″	″ ″	″
Gr. 34	8.1	0 12	43 25	3.8	+ 0.44 ± 0.03	+ 0.29 Auwers
η Cassiop.....	3.8	0 42	57 15	2.1	− 0.02 ± 0.04	+ 0.17 Schur
Ll. 7443	8.5	3 56	35 1	2.2	+ 0.18 ± 0.06	
o^2 Eridani	4.7	4 10	− 7 49	4.0	+ 0.31 ± 0.04	+ 0.17 *Gill*
α Tauri.......	1.0	4 29	16 18	0.2	− 0.07 ± 0.06	+ 0.10 Elkin
W. B. V. 592..	8.7	5 26	− 3 41	2.2	+ 0.24 ± 0.04	
Sirius	− 1.4	6 40	− 16 34	1.3	+ 0.31 ± 0.03	+ 0.38 Gill & Elkin
Ll. 30694.....	7.0	16 47	0 11	1.6	+ 0.03 ± 0.04	
Ll. 31055.....	7.5	17 0	− 4 53	1.5	+ 0.10 ± 0.03	
Σ 2398 *pr*.....	8.2	18 41	59 28	3.1	+ 0.32 ± 0.05	+ 0.35 Lamp
61 Cygni *pr*...		21 2	38 13	5.2	+ 0.21 ± 0.03	+ 0.44 Mean of heliometer determ'nat'ns
B. D. 26° 4721.	8.1	23 53	26 40	0.1	+ 0.26 ± 0.04	

According to Neison every selenographer of consequence has recognized traces of a lunar atmosphere which could not be questioned were it not for the authority of Bessel, whose mathematical analysis of the conditions at the lunar surface has seemed to preclude the possibility of any considerable atmosphere. Neison, justly impugning the validity of this analysis, has contended vigorously for the existence of an atmosphere, not indeed comparable in density with that of the Earth, but sufficient to modify profoundly the physical conditions of the lunar surface, and some recent observers have sought to show the existence of a sensible refraction in the light of an object about to be occulted at the Moon's limb.

It is generally conceded that such a refraction furnishes the most delicate test of the presence of an atmosphere, and although the relation between the physical characteristics of the supposed atmosphere (pressure, temperature, refractive index, law of diminishing temperature with increasing elevation) and the amount of the horizontal refraction is not an altogether simple one, no plausible relation can be assumed among these quantities which will reconcile the absence of refraction with the presence of any considerable atmosphere. Employing for the horizontal refraction and the law of diminishing temperatures the expressions of Laplace (*Méc. Cél.* Liv. X), and assuming the lunar atmosphere at standard temperature and pressure to have the same refractive index as air, I find as an approximate expression for the relation between the horizontal refraction, H, and the density, ρ, of the lunar atmosphere in terms of the Earth's atmosphere at sea level assumed as unity,

$$H = 484'' \rho \left(1 - \frac{\tau}{546}\right)$$

where τ represents the temperature at the Moon's surface in degrees C.

It has been customary to assume upon the authority of the Greenwich occultations that H may be as great as $1''$ or $2''$, but this and all similar determinations appear fatally defective in that the result depends upon an assumed value of the Moon's semidiameter, and I have sought to obtain a value of H free from this assumption by comparing with the filar micrometer of the 40^{cm} Clark equatorial the relative position of two stars as the Moon approaches them; continuing the observations up to the moment of occultation of one of the stars. The distance from the Moon's limb at which the apparent position of a star may be assumed unaffected by the lunar atmosphere depends

upon the extent and density of the latter, and I have provisionally assumed as a result of the analysis leading to the relation between H and ρ above given that if the horizontal refraction does not exceed $1''$ the effect of refraction will not in general be sensible until within two minutes of the occultation of the star.

The observations thus outlined are difficult of execution and stars suitably placed cannot be found at all times, but practice and patience have in some measure overcome these difficulties and have furnished the following results for the amount, $2H$, by which a star at occultation is thrust away from the Moon's limb. Each result is entirely independent of the others and is derived from an immersion at the Moon's dark limb.

Date	2 H	Date	2 H
1897, May 8,	$-0''.3$	1897, July 5,	$-0''.0$
8,	$+0.0$	6,	$+0.7$
9,	$+0.3$	Oct. 3,	-0.6
9,	$+0.2$	3,	$+0.3$
9,	-0.4	3,	-0.8
July 5,	$+0.3$	3,	-0.4

The mean of these results furnishes $H = -0''.03$, which differs from zero by less than its own probable error and which appears to me absolutely irreconcilable with any such value as $H = 1''$, although the number of results thus far obtained is not sufficient to furnish a definitive value. The temperature at the dark limb of the Moon is almost certainly below $0°$ C. and if we adopt this value for τ and take as the maximum permissible value of H, one-tenth of a second of arc, we shall have $\rho = \frac{1}{4840}$, *i. e.*, the maximum density of the permanent lunar atmosphere can not much exceed one-five-thousandth part of the density of the terrestrial atmosphere. If, as has been supposed by some astronomers, ice exists in considerable quantities at the surface of the Moon, the change of temperature which accompanies the transition from night to day may produce a local and temporary atmosphere of aqueous vapor in certain parts of the Moon's surface and it is to be noted that the foregoing observations furnish no information with regard to the presence or absence of such an atmosphere, since they were all made on the night side of the Moon.

GEORGE C. COMSTOCK.

THE AIM OF THE YERKES OBSERVATORY.

By George E. Hale. (Published in the ASTROPHYSICAL JOURNAL, November 1897.)

SPECTRA OF STARS OF SECCHI'S THIRD TYPE.

Professor Keeler showed on the screen a series of photographs of stellar spectra, mostly belonging to Secchi's third type. The slides were positive enlargements (ten diameters) of negatives made with the thirteen-inch refractor and star spectroscope of the Allegheny Observatory. Some of the spectra had been widened, by means of a movable camera, during the process of enlargement. They showed a great amount of detail which can be seen only with great difficulty by direct observation with the spectroscope. Five slides were required to show the spectrum of α Orionis from D to F.

In photographing the less refrangible regions of stellar spectra the chief difficulties arise from the unequal sensitiveness of orthochromatic plates to rays of different wave-lengths. The inequalities of density thus produced can be partially corrected in making the enlargements, by suitably graduating the exposure, but only a comparatively short range of spectrum can be well represented, and a number of different negatives are required to exhibit satisfactorily the whole region which the plate is capable of yielding. This region, however, often contains the most interesting and characteristic features of the spectrum.

The series of slides included the spectra of α Bootis, α Aurigae, α Tauri, α Orionis, α Scorpii, β Pegasi, and α Herculis, in which may be observed a transition from the second to the third type. In stars like α Orionis the lines are essentially those of the solar spectrum, but the relative intensities are not the same, and the general aspect of the spectrum is quite different from that of the spectrum of the Sun. The dark bands characteristic of third-type stars are well shown, though they are not resolved into lines. The separate lines are doubtless far beyond the resolving power of the instrument. These bands are not always terminated by strong metallic lines, and the appearance noted by early observers was probably due to insufficient optical power. The strong lines are mostly those of iron — apparently the low temperature lines. Their relatively greater strength in the star spectrum gives to some well-known solar groups (notably the *b* group) quite an unfamiliar aspect.

In α Herculis only a comparatively few of the strong metallic lines remain, while the bands are deep, and beautifully distinct. It is impossible to avoid the conclusion that the edges of the zones bordering on the dark bands are bright—much brighter, that is, than the average continuous spectrum,—and that they are due to a real predominance of emission at the regions of the spectrum in which they occur. They are not merely the effect of absorption in adjoining regions. In the case of stars like α Orionis, of a less pure type, such a conclusion could not be safely drawn; yet the superior brightness of the spectrum at these places is obvious, and it can be traced even in second-type stars. May there not after all be bright regions in the solar spectrum, such as Draper supposed he had found in the places of the bright oxygen lines? And what is the relation between the dark bands in third-type stars and the bright zones which border on them?

JAMES E. KEELER.

THE STELLAR SPECTROGRAPHIC WORK OF THE EMERSON McMILLIN OBSERVATORY.

In giving an account of my experience in the determination of motions in the line of sight, I would call attention to the great difficulty attending such work when the telescope employed is not corrected for the photographic portion of the spectrum. Numerous attempts were made in the fall of 1896, but the results were unsatisfactory; and the special photographic corrector described in Vol. VI, No. 2, of this JOURNAL was ordered. This lens was not in place until June 1897, and it was not until July that the adjustments were completed so that systematic work could be started. A reflecting slit was employed on account of its superior advantages in following. A 90° total reflecting prism was used to reflect the light from the comparison tube (hydrogen) on the slit. To adjust the comparison tube, the prisms were removed and a ground glass cap placed over the collimator objective; the entire apparatus was then moved until with a wide slit the collimator was shown to be full of light. The slit was then closed to the desired width, about the $\frac{1}{1000}$ part of an inch. In this way a number of photographs were taken which, though for the most part fairly satisfactory, showed some large discordancies. A careful investigation of the instrument was then undertaken and the trouble finally located in the jaws of the slit, as it was found that as the slit was closed a shadow would creep across the collimator objec-

MOTION OF STARS IN THE LINE OF SIGHT.

Plate number	Date 1897	Star	Observed velocity: Red end right	Observed velocity: Red end left	Reduction to the Sun	Velocity reduced to Sun: Red end right	Velocity reduced to Sun: Red end left	Velocity reduced to Sun: Mean	
384	Sept. 3......	γ Cygni	+ 2^{km}.8	— 2^{km}.9	— 5^{km}.2	— 2^{km}.4	— 8^{km}.1	— 5^{km}.2	
387	" 4......		+ 4 .3	± 0 .0	— 5 .4	— 1 .1	— 5 .4	— 3 .2	Mean —4.1.
392	" 7......		+ 2 .9	— 2 .9	— 6 .0	— 3 .1	— 8 .9	— 6 .0	Potsdam mean —6.4
397	" 14......		+ 7 .2	+ 1 .4	— 8 .0	— 0 .8	— 6 .6	— 3 .7	
398	" 14......		+ 8 .6	+ 2 .9	— 8 .0	+ 0 .6	— 5 .1	— 2 .3	
408	" 18......	α Orionis	— 1 .4	— 8 .7	+28 .3	+26 .9	+19 .6	+23 .2	Mean +21.4
414	" 22......		— 7 .2	—10 .0	+28 .3	+21 .1	+18 .3	+19 .7	Potsdam mean +17.2
388	" 4......	ε Pegasi	+15 .8	+10 .1	— 6 .1	+ 9 .7	+ 4 .0	+ 6 .8	Mean +9.9
394	" 10......		+20 .1	+14 .4	— 8 .9	+11 .2	+ 5 .5	+ 8 .3	Potsdam mean +8.0
396	" 12......		+24 .4	+24 .4	— 9 .7	+14 .7	+14 .7	+14 .7	
391	" 4......	α Cassiop.	—12 .9	—17 .2	+12 .2	— 0 .7	— 5 .0	— 2 .8	Mean —0.6
400	" 14......		— 8 .6	—15 .8	+13 .8	+ 5 .2	— 2 .0	+ 1 .6	Potsdam mean —15.2
436	Nov. 17......	α Arietis	± 0 .0	— 4 .3	—10 .4	—10 .4	—14 .7	—12 .6	Mean —14.0
440	" 20......		± 0 .0	— 7 .2	—11 .7	—11 .7	—18 .9	—15 .3	Potsdam mean —14.7

MOTION OF VENUS IN THE LINE OF SIGHT.

Plate number	Date 1897	Observed velocity: Red end right	Observed velocity: Red end left	Observed velocity: Mean	Comp. velocity
403	Sept. 14.......	+11.5	+8.3	+ 9.9	+10.6
409	" 18.......	+12.5	+8.6	+10.6	+10.2
417	" 22.......	+16.5	+4.7	+10.6	+10.1

tive from one side, upon which no adjustment of the comparison tube produced the slightest effect.

The reflecting slit was then replaced by one of the ordinary form and the hydrogen tube placed directly in the cone of rays about seven inches in front of the slit, being turned out of the way during the exposure on the star. A number of photographs of the sky showed satisfactory agreement between the solar and artificial $H\gamma$, the maximum displacement being only $0^{mm}.002$.

As this trouble was not discovered until late in August but few results can be shown. Observations of γ Cygni, α Orionis, ϵ Pegasi, α Cassiopeiae and Venus showed a constant positive difference from the Potsdam results on the stars and the computed velocities of Venus. It occurred to me that this might be due to a personal equation depending upon the direction of the plates under the microscope. In every case the red end had been placed on the right. The plates were remeasured with the red end on the left and a similar negative difference found, the mean of the two agreeing in almost every case with the Potsdam values. The final results together with a few additional ones are given in the table. It should be stated that two dense 60° prisms were employed and that in the neighborhood of $H\gamma$ 1^{mm} displacement on the plate corresponds to a velocity of $143^{km}.7$ per second. The large discordancy in the case of α Cassiopeiae is as yet unexplained.

H. C. LORD.

ON THE APPLICATION OF DIFFRACTION PHENOMENA TO ASTRONOMICAL AND ASTROPHYSICAL MEASUREMENTS.

By F. L. O. Wadsworth. (To be published in the *Bulletin Astronomique*.)

OXYGEN IN THE SUN.

When I asked Professor Hale to put the subject of "Oxygen in the Sun" on the list for the conferences, I thought that we should have a discussion about it. I learned, however, since then, that there is no more occasion for controversy, the former opponent now holding the same views. Let me therefore merely state how the evidence for the presence of oxygen in the Sun now stands.

Professor Paschen and I discovered three strong lines in the utmost red part of that spectrum of oxygen which Schuster has called the compound line spectrum. It is produced in a vacuum tube by an induction

current, without a Leyden jar and without a spark gap. On measuring these three lines we found that they coincided as nearly as we could make out, with three Fraunhofer lines that we found in the photographs made of this region by McClean and Higgs. The relative intensities were also the same, and this region of the spectrum not having many lines, there remains very little doubt that the coincidences are real. As to the proof of the presence of oxygen in the Sun, it therefore only remained to be shown that these three lines are not produced in the Earth's atmosphere, but that they are true solar lines.

When Paschen and I published this result, Mr. Jewell immediately took up the question. He examined the three Fraunhofer lines and came to the conclusion that they were atmospheric lines due to water vapor. Now this conclusion seemed to us very impossible indeed. We were ready to accept the view that the lines were due to atmospheric oxygen. But that they were due to water vapor would make the coincidences with the lines of the vacuum tube accidental, and three lines coinciding with lines of the same relative intensities in a region that contained so few lines, we could not believe to be a matter of chance. It was for this reason that I asked Professor Hale to let me have a discussion with Mr. Jewell at the conferences. Since his first observations, however, Mr. Jewell has not remained satisfied with the evidence, and he found that he had been misled by the want of a proper absorbent of the second order spectrum, that overlaps the first order spectrum, in which he was observing. The second order spectrum makes the Fraunhofer lines of the first order shine with violet light, and as the absorption of the violet light increases more rapidly with the Sun's zenith distance than the absorption of red light, the first order lines seemed to increase in intensity. After he found the right sort of absorbent to cut off the second order he repeated his observations, and the result is that he now withdraws his first conclusion. He finds that as far as his observations go the intensity of the three lines in question alters in the same way as true solar lines.

One might therefore almost say that the presence of oxygen in the Sun is proved. Further evidence is gained from other lines. Paschen and I have shown that this red triplet is the first member of a principal series. We have found and measured the second member, a triplet of the same build but much narrower,— as narrow as the laws of the principal series requires it to be. This triplet also coincides with Fraunhofer lines, only that the middle line is hidden by an iron line. The

other two lines, however, agree in position satisfactorily with Fraunhofer lines of unknown origin. These Fraunhofer lines are undoubtedly true solar lines, because on negatives made at Johns Hopkins University they show by their shifting the motion of the Sun's limbs in the line of sight. This proof of the presence of oxygen in the Sun I would regard as conclusive, if the lines in this part of the solar spectrum were not so closely set. The evidence of a real coincidence is inversely proportional to the density of the lines, and therefore it is much more convincing in the red part of the spectrum.

The proof would be conclusive if it were shown that the three red lines shift on the limbs of the Sun, and we hope that some one better equipped for this kind of work than we are will take up the subject and will once for all settle the question. C. RUNGE.

EFFECT OF PRESSURE ON WAVE-LENGTH.

Increase of pressure about an electric arc increases the wave-lengths of the spectral lines so produced. This increase is very different for different elements and also for different series of lines of the same element, but the results of the investigation can be expressed fairly well by the simple equation :

$$\Delta \lambda = \alpha \beta \lambda (p - p_0)$$

where $\Delta \lambda$ is the increase of wave-length λ of any given line produced by the increase of pressure $p - p_0$, β a constant for any series of lines and α a constant for any element. That is β for any series of a given element is the same as β for the corresponding series of any other element, while α for any series of a given element is the same as α for any other series of the same element. If we write β_0 for the principal series, β_1 for the first subordinate, and β_2 for the second subordinate, then, approximately, $\beta_0 : \beta_1 : \beta_2 = 1 : 2 : 4$.

By suitably choosing β, α may be replaced in most cases by $\frac{1}{T}$, where T is the absolute temperature of the melting point of the element in question, or by $e\sqrt[3]{V}$, where e is the coefficient of linear expansion of the substance in the solid state and V the atomic volume, or finally, for either half of a Mendelejeff group, by $\sqrt[3]{W}$, where W is the atomic weight. From this last expression it is evident that α, and therefore $\Delta\lambda$, is a periodic function of atomic weight, and consequently the shifts of spectral lines may be compared directly with any other phenomenon which itself is a periodic function of atomic weight.

W. J. HUMPHREYS.

THE LATITUDE WORK OF THE FLOWER OBSERVATORY.

I have been asked to give an informal account of the latitude work now in progress at the Flower Observatory, University of Pennsylvania. As to the method — nothing particularly new is involved. It is a continuation with a better instrument and under what are believed to be more favorable conditions of the work upon which I was engaged for a number of years at the Sayre Observatory, Bethlehem.

The instrument is a zenith telescope of four inches aperture and forty-eight inches focal length, by Warner and Swasey.

We have introduced a feature not usually found in connection with this class of instruments, viz., two pairs of long focus collimators, or mires for the purpose of facilitating the adjustment in azimuth and collimation. The latter is somewhat troublesome with instruments of this type ; the telescope not being symmetrically placed with respect to the vertical axis it is not possible to test the adjustment by simple reversal as with the transit instrument. It was a matter of time and patience to place these four mires in position and to adjust them perfectly, but they have proved to be very stable, and by their use the latitude instrument can readily be kept in such perfect adjustment that any star found on the observing list will come to the middle thread within a fraction of a second of its appointed time.

Four groups of stars have been employed for latitude : three groups contain ten pairs, and one group nine. Elsewhere in some cases the number of pairs in a group has in some cases been limited to six or seven ; possibly seven pairs will give results nearly as good as ten. However, when the instrument has been adjusted and six or seven pairs observed it involves but little additional trouble to observe two or three more.

It is an easy matter to state the condition to which an ideal star list should conform, but like other ideals this one cannot be realized in practice. Although much time has been expended upon the present list it falls short of perfection in a number of important particulars. In several cases the choice lay between the admission of long gaps in the series or the filling of these gaps with pairs which were objectionable in one way or another. As a matter of fact, in so far as can be discovered from internal evidence, these less desirable pairs appear to give nearly as good results as those which seemed to be deserving of more confidence.

The distribution in right ascension is as follows:

Group	I	$5^h\ 28^m$ —	$7^h\ 9^m$
"	II	12 48 —	14 52
"	III	17 19 —	19 26
"	IV	21 29	23 28

Observation began October 1, 1896.

Groups IV and I	were observed	from	Oct. 1	to	Nov. 27, '96
Group I alone	"	"	"	Dec. 14	"	Jan. 11, '97
Groups I and II	"	"	"	Jan. 23	"	Mar. 13, '97
Group II alone	"	"	"	Mch. 16	"	Apr. 20, '97
Groups II and III	"	"	"	May 7	"	June 2, '97
Group III alone	"	"	"	June 18	"	July 4, '97
Groups III and IV	"	"	"	July 5	"	Aug. 26, '97
Group IV alone	"	"	"	Sept. 18	"	Sept. 28, '97
Groups IV and I	"	"	"	Oct. 4	"	date.

The internal probable error of a single determination as derived from each group separately is as follows:

I, 0".135 II, 0".139 III, 0".137 IV, 0".142

The reduction has been kept well in hand and results are available up to August 26th. They are as follows:

$\phi = 39°\ 58' +$

1896	Oct. 1 – Oct. 31	IV	1".878	I	1".945	Mean	1".912
"	Nov. 1 – Nov. 27		1 .783		1 .939	"	1 .861
"	Dec. 14 – Jan. 11				2 .079	"	2 .079
1897	Jan. 23 – Feb. 16	I	2 .067	II	2 .117	"	2 .092
"	Feb. 23 – Mar. 13		2 .060		2 .231	"	2 .145
"	Mar. 16 – Apr. 20				2 .262	"	2 .262
"	May 7 – May 21	II	2. 200	III	2 .322	"	2 .261
"	May 22 – June 2		2. 202		2 .301	"	2 .251
"	June 18 – July 4				2 .246	"	2 .246
"	July 5 – July 31	III	2 .132	IV	2 .307	"	2 .220
"	Aug. 2 – Aug. 26		2. 243		2 .291	"	2 .267

Although these results are in a manner preliminary it is not likely that any great modification will follow a more elaborate discussion. The agreement with Chandler's theory is very satisfactory, except that the last two values differ somewhat more than the computed probable error would lead us to anticipate.

For the purpose of illustrating more fully the character of the work,

the individual values are given for group I, Dec. 14–Jan. 11. The third place given above is from the mean of these.

			1	2	3	4	5	6	7	8	9	10	Mean
1896	Dec.	14	2″.34	2″.25	2″.21	2″.44	2″.39	2″.30	2″.35	1″.90	2″.32	2″.28	2″.28
"	"	23	2 .05	2 .32	2 .24	2 .59	2 .23	2 .13	2 .26	2 .18	2 .47	2 .08	2 .25
"	"	24	1 .90	2 .01	1 .85	2 .33	2 .32	1 .96	2 .44	1 .83	2 .18	2 .47	2 .13
"	"	25	1 .99	1 .73	1 .77	1 .90	1 .82	1 .67	2 .00	1 .72	1 .80	1 .91	1 .83
"	"	27	2 .48	2 .19	2 .43	2 .25	2 .60	2 .56	2 .58	2 .41	1 .97	2 .03	2 .35
"	"	28	1 .85	2 .16	2 .30	1 .88	2 .06	1 .85	2 .01	2 .10	1 .94	2 .01	2 .02
"	"	31	2 .10	2 .34	....	1 .85	2 .45	2 .20	2 .23	2 .34	....	2 .15	2 .21
1897	Jan.	6	1 .87	2 .12	2 .14	2 .25	2 .09	1 .75	2 .07	2 .12	1 .72	2 .17	2 .03
"	"	7	2 .12	2 .05	2 .48	2 .28	2 .13	2 .38	2 .18	2 .15	2 .25	2 .06	2 .21
"	"	10	1 .95	1 .93	2 .30	1 .90	2 .60	2 .17	2 .54	2 .58	2 .56	2 .41	2 .29
"	"	11	1 .91	2 .25	2 .29	2 .18	1 .92	2 .47	2 .29	2 .19	2 .15	1 .96	2 .16

These values are reduced to the mean declination of the group, hence they are strictly comparable. It will be observed that the extreme range is 0″.97. The probable error of a single observation computed from this series alone is 0″.127. That of a single night's work of ten determinations is 0″.40, yet it will be noticed that with one exception every value on December 25 is smaller than that determined from the corresponding pair on the 24th, and without exception smaller than the corresponding value on the 27th, the daily means being for the 24th 2″.13, 25th 1″.83, 27th 2″.35. Thus the difference between the 25th and 27th, 0″.52, is thirteen times the probable error of an evening's determination.

Many series of zenith telescope latitudes have been examined, and in nearly every case similar anomalies have been found, in some cases the difference being much greater than the above. This seems to point unmistakably to some outside disturbing cause, presumably due to atmospheric disturbance. This will apparently be very difficult to deal with, but unless means can be found for doing so it would seem that we have about reached the limit of accuracy attainable in this class of work.

C. L. DOOLITTLE.

THE WORK OF THE COLUMBIA UNIVERSITY OBSERVATORY.

At the request of the Director, Professor George E. Hale, the work carried on at the Observatory of Columbia University was described briefly by Professor J. K. Rees, the Director of the Columbia University Observatory.

Professor Rees referred to the work of the Observatory staff on (1) The Determination of the Variation of Latitude at New York City; (2) The Value of the Constant of Aberration by Küstner's Method; (3) The Reductions of the Measures of the Rutherfurd Photographs; and (4) Investigations on Polar Trail Plates.

(1) In April 1893, arrangements were concluded between the Royal Observatory at Capodimonte, Naples, of which E. Fergola is the Director, and the Observatory of Columbia University for observing the same stars with two zenith telescopes, made by Wanschaff of Berlin. These instruments have apertures of eighty millimeters and focal lengths of one meter and are in all respects exactly alike. The two latitude levels on each instrument are by Reichel of Berlin. Before leaving Berlin the instruments were tested by Dr. Albrecht. Fifty-six stars, divided into four groups of seven pairs each were observed. The investigation of the declinations of these stars was made by Professor Jacoby and Dr. Davis, and has been published as Part I, *Memoir I of the New York Academy of Sciences.* This publication is also No. 8 of the *Contributions from Columbia University Observatory.* Both Observatories have issued recently preliminary publications of the results of their work for the period May 1893 to July 1894.[1]

The following tables show the variation of latitude at the two places:

AT NEW YORK CITY.

	Date		Latitude[2]	Variation
1893	May	19,	40° 48′ 22″.19	+ 0″.00
"	June	18,	.20	+ .01
"	July	14,	.21	+ .02
"	Aug.	1,	.09	— .10
"	Oct.	17,	.28	+ .09
"	Nov.	15,	.16	— .03
"	Dec.	13,	.27	+ .08

[1] "The Variation of Latitude at New York and a Determination of the Constant of Aberration from Observations at the Observatory of Columbia University," by J. K. Rees, H. Jacoby, and H. S. Davis, *Astronomical Journal*, No. 401.

"Novella Determinazione della Constante dell' Aberrazione e della Latitudine di Napoli da Osservazioni fatte nel R. Osservatorio di Capodimonte negli Anni 1893–94 per E. Fergola."

[2] The Latitude Observatory is about three and one-half miles north of the University Observatory.

AT NEW YORK CITY—*continued.*

Date		Longitude	Variation
1894	Jan. 18,	.18	— .01
"	Feb. 15,	.19	— .00
"	Mch. 14,	.17	— .02
"	Apr. 12,	.21	+ .02
"	May 15,	.19	— .00
"	June 13,	.13	— .06
	Mean	22.19	

AT NAPLES.

Date		Latitude	Variation
1893	May 18,	40° 51′ 45″.72	— 0″.02
"	June 16,	.70	— .04
"	July 16,	.70	— .04
"	Aug. 14,	.67	— .07
"	Sept. 12,	.68	— .06
"	Oct. 16,	.73	— .01
"	Nov. 12,	.76	+ .02
"	Dec. 14,	.78	+ .04
1894	Jan. 17,	.74	+ .00
"	Feb. 14,	.81	+ .07
"	Mch. 14,	.75	+ .01
"	Apl. 15,	.81	+ .07
"	May 14,	.82	+ .08
"	June 13,	.78	+ .04
	Mean	45.74	

At Naples Professor Fergola observed alone. His latitude determinations depend upon 2271 pairs of stars. At New York City, the observers were Professors Rees and Jacoby and Dr. Davis. These observed 1774 pairs of stars, as follows: Rees, 809; Jacoby, 299; and Davis, 666.

Since July 1894 the observations have been continued, but on a reduced scale. Four good nights every two weeks are sought. The observations at Naples are now being made by Doctors Angelitti and Contarino, and the observations at Columbia University, by Professor Rees and Dr. Davis. Results of the later series will be ready soon for publication. In this connection it is proper to state that the complete reductions of all the observations as Part II, *Memoir I of the New York Academy of Sciences*, and No. 9 of the *Contributions from*

the Columbia University Observatory will be made with funds provided by the generous contribution of Miss Catherine W. Bruce of New York City.

(2) At New York City and at Naples, the Constant of Aberration has been determined from the first series of observations without making any assumption in regard to the law of latitude variation, either as to period or as to amplitude. The value obtained at the Columbia Observatory was $20''.46$, and at the Royal Observatory at Naples $20''.53$. The difference in the results seems to indicate that there is some systematic error in the method, unless some error be discovered in the computations which will bring them into better agreement. Circumstances were unusually favorable to the method, and a better agreement was to be expected. In the present state of our knowledge, we prefer to leave further conclusions to await the reductions of the later series of observations.

(3) The son of Lewis M. Rutherfurd, Rutherfurd Stuyvesant, Esq., has provided the means since his father's death for carrying on the work of the reductions of the measures of the star plates made by Rutherfurd, and also for measuring the plates unmeasured by Rutherfurd, and for reducing such measures. Mr. Stuyvesant has also provided the means for making the various publications. The work has been under the special charge of Professor Jacoby.

The Observatory has published in the *Annals of the New York Academy of Sciences*, and in its own list of *Contributions*, the following papers:

BY PROFESSOR JACOBY:

The Rutherfurd Photographic Measures of the Group of the Pleiades. *Annals of the New York Academy of Sciences*, Vol. VI, and *Contributions from the Columbia University Observatory*, No. 3.

The Rutherfurd Photographic Measures of the Stars about β Cygni. *Annals of the New York Academy of Sciences*, Vol. VI, and *Contributions from the Columbia University Observatory*, No. 4.

The Parallaxes of μ and θ Cassiopeiæ, from Rutherfurd Photographic Measures. *Annals of the New York Academy of Sciences*, Vol. VIII, and *Contributions from the Columbia University Observatory*, No. 5.

On the Reduction of Stellar Photographs, with special reference to the Astro-Photographic Catalogue Plates. On the Permanence of the Rutherfurd Photographic Plates. *Annals of the New York Academy of Sciences*, Vol. IX, and *Contributions from the Columbia University Observatory*, Nos. 10 and 11.

BY DR. H. S. DAVIS:

The Parallax of η Cassiopeiæ, deduced from the Rutherfurd Photographic Measures. *Annals of the New York Academy of Sciences*, Vol. VIII, and *Contributions from the Columbia University Observatory*, No. 6.

The Rutherfurd Photographic Measures of sixty-two stars about η Cassiopeiæ. *Annals of the New York Academy of Sciences*, Vol. VIII, and *Contributions from the Columbia University Observatory*, No. 7.

The Parallax of 61 Cygni, from the Rutherfurd Photographic Measures; the Parallax of Bradley 3077, from the Rutherfurd Photographic Measures. *Annals of the New York Academy of Sciences*, Vol. X, and *Contributions from the Columbia University Observatory*, No. 12.

All of the Rutherfurd photographs were made with wet plates. He left a number of important plates unmeasured. Before proceeding to the measurement of these plates on the Repsold machines belonging to the Observatory, the investigation on the permanence of the Rutherfurd plates was made. This investigation shows that measures can now be undertaken without any apprehension as to the movements of the collodion film.

Mr. F. Schlesinger, Fellow in Astronomy, and Mr. W. C. Kretz, University Scholar in Astronomy, are now at work measuring and reducing the plates of the Præsepe Cluster and the Cluster in Coma Berenecis.

(4) Professor Jacoby has undertaken the measurement of polar trail plates made at his request by Dr. Donner of Helsingfors. From the reduction of these measurements, he hopes to get a fundamental system of right ascensions and polar distances of the close polar stars. The method may, in the future, lead to values of the constants of precession, nutation, and aberration, which will be superior to the best meridian determinations. The results of the preliminary investigations will shortly be made public.

THE PHOTOCHRONOGRAPH.

THE instrument used at the Georgetown College Observatory for the photographic registration of star transits was devised by the Rev. George A. Fargis, S. J., and was the sequel of one devised by Professor Frank H. Bigelow of the Weather Bureau, whose first experiments had been made at Harvard with the help and suggestions of Professor Pickering. In Professor Bigelow's instrument, the photographic plate, enclosed in a holder, was moved up and down each second by an electro-magnet in a clock circuit. The motion broke up

the continuous trail, which would have been made by the star as it crossed the field, into two parallel lines of dots or dashes, each impressed on the plate during a given second of time. The reticle, which lay a little in front of the plate, was then impressed on it by throwing a light through the object glass and down the telescope, thus slightly fogging the plate except where it was covered by the wires of the reticle, which showed bright on a darkened ground. (Professor Bigelow's device was shown.)

Professor Bigelow being called away from Washington for some time, further experiments were undertaken by Father Fargis to remove what seemed to be imperfections in the first device. These were, the motion of the plate, the weight of the moving parts, the danger of parallax on account of the distance between the reticle and the plate, which was needed in order to permit the motion of the latter, and the fogging of the plate in the neighborhood of the rows of star images when photographing the reticle on the plate.

The method of doing this last was retained, as it did not seem to leave anything to be desired, if the neighborhood of the star images could be protected. Instead of spider lines a glass plate was used on which a single line was ruled. This was interrupted for a short distance in the middle of the field, so as not to interfere with the star images. The plate-holder was discarded and the bare plate used. As the plate had not to move, it was placed and held firmly almost in contact with the glass reticle. With a somewhat different arrangement it might have been quite in contact. In order to break up the star trail into portions impressed on the plate at definite times, the following arrangement was devised. A small electro-magnet had fastened to its armature at right angles a thin strip of steel, long enough to reach nearly across the field of the telescope and broad enough to cut off the cone of light from a star at a point near the focus. The whole weighed only a few ounces, the moving parts weighing only about a quarter of an ounce or less. It was carried by a clamp-ring around the draw-tube of the telescope and was placed near the reticle end, the steel finger, or shutter, stretching across the field through an opening in the draw-tube a little on the object-glass side of the reticle. The electro-magnet was in a clock circuit. (This instrument, the photochronograph, was shown.)

The action of the photochronograph may be explained by a comparison with the ordinary register of clock times or a barrel chrono-

graph. The telescope was so set that, with the armature of the electro-magnet down, the image of the star fell on the steel finger, or shutter, and was cut off from the plate. The breaking of the circuit by the clock, instead of making a signal on a sheet of paper, released the armature, causing the shutter to rise and allowing the star image to fall on the plate while the break lasted. Thus a series of impressions on the plate took the place of the ordinary register. The clock times were written on the plate instead of on the chronograph sheet and by means of the light of the star. This suggested the name given the instrument. When a sufficient number of impressions had been secured, a light was thrown through the objective and the recticle photographed directly on the time-scale, thus doing automatically what the observer does by his signals in the ordinary chronographic registry of transits. While the reticle was being photographed, the shutter was kept covering the row of star impressions, protecting this part of the field from fogging. (Some plates containing transits were shown.)

When the plate is measured in a microscope-micrometer, the time of transit over the wire can be deduced from each impression. By pairing those nearly symmetrical with the wire, in a full transit the micrometer screw-value is never needed to determine more than half an equatorial second. The screw-value itself is found from the time-scale, or row of star images. This measurement of the plate gives rise, of course, to the possibility of personal equation. Such was actually found in the Georgetown plates, arising seemingly from the use of a single wire in the micrometer. But in the photographic method, the transit is fixed on the plate, which may be measured by many persons, at any time and in any way which may be devised for eliminating personal error.

In order to test the method, the Ertel transit of the Georgetown College Observatory was fitted up and an extensive trial made. The results of this trial have been published. The following are the conclusions which are of particular interest.

As determined by the agreement *inter se* of the impressions on single plates, the probable error of a single image was $\pm 0^s.035$. Albrecht's *Hülfstafeln* give for the magnifying power of our telescope and microscope combined, at the equator, $\pm 0^s.075$ for eye and ear and $\pm 0^s.057$ for the chronograph, and the same as for the photographic method at the declinations $71^\circ.4$ and $66^\circ.0$, respectively. The breadth

in declination of the star images was usually from $3''$ to $5''$. Contrary to expectation, it was less with increasing declination.

The usual time of exposure was a tenth of a second. With this stars could be taken down to $3^m.5$, or sometimes fainter ones, though not all of $3^m.5$ could be taken. Some stars had a whole second exposure, but enough were not taken to form a judgment. The aperture of the Ertel transit is 4½ inches and its focal length 78 inches, or the ratio is 1 to 17. For several reasons, the photochronograph has been used in a series of observations for latitude by photography. With a whole second exposure, stars could ordinarily be taken as faint as the sixth visual magnitude. The zenith telescope used is better adapted to photography. Its aperture is 6 inches and its focal length 36 inches, or the ratio is 1 to 6. Such a telescope does not differ widely in weight and cost from the usual portable transit.

Obviously, one of the principal applications of the photochronograph is to the determination of longitudes. The probable error of the clock correction when at its minimum was found to be $\pm 0^s.01$. Its square at the time T, in hours from the moment of minimum probable error, was found to be $(0^s.01)^2 + (0^s.01)^2\ T^2$. The average number of stars each night which gave these probable errors was 20, including both time and azimuth stars. As there were no collimators, the method usual with portable instruments was followed, the instrument being reversed in its V's during each night's work.

JOHN T. HEDRICK, S.J.

PERSONAL EQUATION IN LONGITUDE DETERMINATIONS.

All determinations of the difference of longitude of two meridians consist of two operations, whether the method employed be that of telegraphic determination, Moon culminations, or occultations. These operations are:

(1) The determination of the local time at each station.

(2) The comparison of timepieces.

By the telegraphic method, clocks 1000 miles apart can be compared, over land lines, with practically the same accuracy as if they stood in the same room. The errors, therefore, of the longitude determination are to be found in the first of the operations mentioned; namely, in the determination of the local time.

In the star observations made at each station, every star observed will give an equation of the form:

$$\alpha - t = \Delta t + Aa + Bb + Cc + k$$

where α = R. A., t = observed time. ΔT = clock correction.

$a, b, c,$ = azimuth, level and collimation constants respectively.

k/ $\cancel{k}$ = correction on account of daily aberration.

It is desired to determine Δt, the clock correction; with ten or twelve stars properly chosen, the effect of azimuth and collimation is completely eliminated; the correction for aberration is a small one, and is known with great exactness. The uncertainties in R.A. will not affect the agreement of results from night to night if the same list of stars is employed. There remain, therefore, only two terms in this equation whose uncertainty will cause discrepancies in the individual results. These are (1) errors in the level constant b; (2) errors in the observed time t.

I. The effect of errors in the level is probably more serious than is generally suspected. A slight pinching of the tube in the cell and the consequent change of the radius of curvature may make sudden and rather large changes. These, however, are not now under consideration.

II. The errors in t are due to accidental errors and to personal equation in observing star transits.

It is generally considered safest to exchange observers and consider the personal equation eliminated thereby. For some years past the writer has made a large number of determinations of longitude in conjunction with Mr. S. S. Gannett, of the U. S. Geological Survey. The personal equation could not be got rid of by exchanging observers. It has, therefore, been determined at the beginning and end of the season's work. The determination was made by setting up the two transits on two piers in the Observatory of Washington University, St. Louis, and determining their difference of longitude in exactly the same way that the regular longitude determinations were made, taking all possible precautions to avoid the effect of contiguity.

The following results show the probable errors of a single night's work (from the individual longitude results) for different distances. The first result is the probable error in the determination of the longitude of the two piers, which were only six feet apart.

Probable error of one night's exchange	Distance between Stations in miles	Number of Repeaters in circuit
$\pm 0^s.048$	0	0
± 0.041	271	0
± 0.049	585	1
± 0.031	1531	2

As these results depend upon a large number of observations, extending over six years, they may be considered as fairly indicating the relative probable errors under the different circumstances mentioned.

Two conclusions seem fairly safely shown:

In the first place, the accuracy of longitude determinations over land lines seems independent of the distances.

Secondly, the experience of the two observers seems to indicate that their relative personal equation, while fairly constant from year to year, was subject to sudden and large fluctuations from night to night, and even in the progress of a night's work.

HENRY S. PRITCHETT.

A POSSIBLE FORM OF MIRROR FOR REFLECTING TELESCOPES.

The mirror in question is a section of a paraboloid of revolution, cut at the extremity of the latus rectum. Such a mirror has the property of bringing to a single focus all the rays parallel to the axis of figure, and the axis of the reflected pencil is perpendicular to that of the incident beam: the mirror thus performing the functions of a parabolic mirror of the ordinary form and of a plane mirror placed at an angle of 45 degrees.

The advantages of this form are, *first*, that a single reflection takes the place of two; *second*, that there is no secondary mirror in the path of the incident rays. Thus the entire surface of the mirror is utilized and the image should be free from the diffraction bands caused by the support of the flat in the old style; *third*, the resulting form of equatorial mounting is extremely simple. The telescope tube becomes the declination axis, the mirror being mounted at the extremity of this axis in a manner entirely similar to that of the large flat of the Equatorial Coudé. The image formed by the mirror is therefore at the intersection of the declination and the polar axis, and remains in a constant position, no matter on what part of the heavens the telescope may be directed. This offers great advantages for the observer, and for the attachment of special appliances, such as spectroscopes. Further, no dome is required.

From experiments made at the Johns Hopkins University in grinding and polishing such a mirror, it may be safely concluded, that such a form, while extremely difficult to make, is not impossible. A small mirror has actually been constructed on these lines and is now being experimented with.

It was suggested that further experiments be carried out at the Yerkes Observatory, the facilities for glass working in the latter place being far superior to those of the Johns Hopkins. CHARLES LANE POOR.

THE SOLAR MOTION AS A GAUGE OF STELLAR DISTANCES.

1. The numerical quantity of the solar motion, expressed in units of terrestrial measure, say kilometers per second, can best be determined by measurements of the motion of stars in the line of sight. I find that Vogel's measures give a velocity of about ten kilometers per second, with a mean error of perhaps one-half its whole amount. While these measures are not sufficiently numerous to lead to a definitive result, it may be hoped that, in the not distant future, more determinations will be made.

2. The parallactic motion of a single star does not admit of absolute determination. But for groups or classes of stars situated not near the Sun-way apex or anti-apex, the motion can be determined. In my investigation of the precessional constant I found evidence that the mass of the Bradley stars of magnitude 6 and upwards near the Sun-way equator have a parallactic motion exceeding $2''$ per century, this quantity being near the limit of the motion for the stars in question.

3. From these two data it would follow, by a very simple computation, that the great mass of the Bradley stars are contained within a sphere whose surface has an annual parallax of $0''.01$.

4. In the same paper (p. 24), I found that the Bradley stars whose parallactic motion exceeds $10''$ per century probably numbered about 342. From a solar velocity of 10 kilometers per second it would follow that these stars have an annual parallax of $0''.05$ and upwards.

5. The determination of the parallactic motion of the fainter stars is among the desiderata of astronomy in the immediate future. Very valuable for this purpose would be the re-observation of the Harvard equatorial zones, found in the early volumes of the Harvard *Annals*. These have the great advantages that each star was observed twice, and that much fainter stars are included than are found in the older zones.

S. NEWCOMB.

ON THE MEANING OF THE STAR MAGNITUDES OF FATHER HAGEN'S ATLAS OF VARIABLE STARS.

As to the general plan of the Atlas Father Hagen referred to his account given a year ago at the astronomical meeting in Bamberg,

and printed in the *V. J. S.*, **31**, 278. The accuracy intended in the ***positions*** of the stars in the Atlas will be sufficiently understood from the preface of the work, but the ***magnitudes*** of the stars seemed to call for an explanation.

The brightness of the stars was not estimated directly in magnitudes, but in relative steps between the stars, and the question arose how to transform these steps by computation into magnitudes.

Before answering this question it may be instructive to compare the work of this Atlas with that of a *Durchmusterung*. The purpose of the latter is to spread a uniform scale of magnitudes all over the sky, while accidental errors in the individual star magnitudes are of minor importance. In an atlas, however, which is to serve for the light variations of the stars, the relative brightness of the comparison stars is the main purpose, while a uniformity of scale between the individual charts is of little consequence. Now it is admitted by all observers of variable stars that the relative brightness of the stars is obtained with greater accuracy from steps than from magnitudes.

In transforming the steps into magnitudes the first condition must be to adapt the computed scale of magnitudes as closely as possible to some standard scale already existing. It was shown in the lecture at Williams Bay, that this condition is incompatible with a uniform lower limit of magnitude for all the charts, and that this limit varies within the magnitudes 11½ and 13½, for the Georgetown refractor of 12 inches aperture. It will be sufficient here to mention that this variation of the limit of magnitudes was referred to several causes. First, the limit of visibility in any instrument cannot be assumed to be the same for all parts of the sky and all times of the year. Then the light ratio from the brighter to the fainter stars cannot be assumed constant in any scale which was made without photometric instruments. Finally the scale itself may not be uniform for all parts of the sky.

Considering these uncertainties it was thought best to compute for each chart a step value which would bring the computed magnitudes in close agreement with a standard scale, say the Bonn ***Durchmusterung***, and to apply the same to the fainter stars, without regard to the limit reached on the several charts. In using the charts and the accompanying catalogue it must then be borne in mind that the magnitudes assigned to the stars below the tenth magnitude are by no means meant to be a ***continuation of the BD. scale***, but merely *the result of a computation, in which a close agreement with the BD. within the magnitudes*

7 and 10 was intended, and where the step-value thus found was applied to the fainter stars, without regard to the limit which would be thus reached.

These magnitudes fully answer the purpose for which they are intended, viz., to enable the engraver to represent on the charts the relative brightness of the stars. The observer of variable stars will thus be enabled to recognize the configuration and to identify the variable, while in his reductions and computations of the light curve and period of light variation, he will discard the magnitudes altogether. He will not even use the steps, printed in the second column of the Catalogue, except as a guide in choosing his comparison stars, because his observations will furnish him his own scale. The steps may be of use later when a photometric scale shall have been constructed for the fainter stars. It will then be an easy matter to determine, by a graphical process, the varying step-values by which our steps are adapted to this or any other new scale. A specimen chart was passed around during the lecture, and the columns of the Catalogue were represented on the blackboard. At the end of the lecture the announcement was made that Miss Catherine W. Bruce had liberally granted the indemnity for the publisher, which was necessitated by the great expense of the engraving. It was mentioned also that astronomers owe this gift to the kind commendation of Professor E. C. Pickering. These announcements were received with applause. It may be added that the I Series of the Atlas is now in print, and that the publication is in charge of Mr. F. L. Dames, Berlin (Voss-Strasse 32).

THE SYSTEM OF β LYRAE.

By G. W. Myers. (To be published in the ASTROPHYSICAL JOURNAL, January 1898.)

JOVIAN PHENOMENA.

THE planet Jupiter exhibits the greatest variety of phenomena of any planet belonging to the solar system. The surface markings may be seen with a small telescope, and from the time of Galileo to the present day the planet has been studied by astronomers, and a great number of facts have been collected regarding the changes taking place on the surface. Until within recent years it seems to have been assumed that there was no great degree of permanency in the markings.

New belts are stated to have been formed in a few hours, and in the course of a month or two the whole aspect of the disk was changed.[1]

I began a systematic study of the physical features of the planet in 1879 with the 18½-inch refractor of the Dearborn Observatory, and have continued the observations to the present time.

Very early in my study it seemed to me that the surface exhibited a much greater degree of permanency than had hitherto been admitted.

The result of eighteen years of observations shows that the changes which are continually taking place on the surface of the planet are effected in an orderly manner; some of the prominent features persisting for years with very slight changes in form or position on the disk.

The south margin of the equatorial belt and the great red spot are conspicuous examples of permanency.

In order to deduce conclusions of any value, regarding the condition of the surface of any planet, it is desirable to have a continuous record of phenomena over a long period and not isolated observations at irregular intervals.

The astronomer of today, provided with the largest telescope, and most favorable atmospheric conditions, cannot formulate a theory regarding the physical condition of a planet, which will be of any value to science, by simply noting what is seen with his telescope during one night or one opposition.

During recent years statements have occasionally been made with regard to the variation in magnitude and displacement of objects on the disk of Jupiter, which, unless properly interpreted, are misleading as to the nature of the actual phenomena.

The following considerations will elucidate the subject:

1. As the observer is looking at a rotating globe, having the axis nearly perpendicular to the line of sight, objects will cross the disk in nearly straight lines, but the linear velocity will be greatest at the equator and least in higher latitudes.

2. All objects, when they are brought in view by rotation, will be infinitely short, and as they advance farther on the disk, the apparent length will increase until the center of the object is on the middle of the disk, when it will be the longest possible; after it passes the center, the length will appear to gradually shorten until it passes behind the disk at the preceding limb.

[1] *Vide* GRANT'S *History of Physical Astronomy*, etc.

3. In case a spot near the equator and one end of the great red spot happen to lie on a line parallel to the polar axis of the planet, the equatorial spot may deviate from this line $2''$ or $3''$ of arc, while under the eye of the observer; owing to the change in the length of the red spot as well as the unequal linear velocity due to difference of latitude.

From 1879 to 1884 two conspicuous equatorial white spots passed the great red spot at intervals of forty-five days, when the apparent shifting of the spots with reference to each other was well illustrated.

4. During the revolution of the planet in its orbit, all objects on the disk will be displaced in latitude, due to the elevation of the Earth above Jupiter's equator. Objects near the equator of the planet may be displaced $\pm 1''.1$ of arc, and those in higher latitudes a less amount.

5. On account of the rapid foreshortening of the degrees of latitude in the polar regions, spots or detached markings are found only in the equatorial and middle latitudes. It is seldom that a spot is seen beyond the parallel of $40°$.

The parallel of $70°$ is at one second of arc, and that of $80°$ at one-quarter second of arc from the limb, hence the polar regions are entirely beyond our reach.

6. Since all markings are only seen in their normal proportions when on the central meridian of the disk, it would be a difficult matter to decide whether any actual change occurred in the shape or size of the object in its passage across the disk.

In 1880 when the red spot was most intense in color it was seen coming on the disk when the true center was at $88°$ from the central meridian and its computed length one second of arc.

When the spot is wholly on the disk, the true center is $71°$ from the central meridian and the apparent length is $3''.71$.

When the center is on the central meridian the length is $11''.61$ or $37°.6$ of longitude and the breadth is $3''.6$.

In the study of the surface markings on Jupiter, the longitude, latitude and magnitude of the object has invariably been determined with the micrometer.

For all micrometer measurements, however, which are referred to a luminous disk, it is essential to employ both limbs, in order to eliminate the effect of irradiation, or what is of greater importance the enlargement of the disk due to bad definition.

The great red spot has been observed during every opposition since 1879 and its motion in longitude and latitude ascertained.

The equatorial belt and the various black and white spots have also been observed annually, except during the year 1888 when the telescope was dismounted.

The true rotation period of the planet is unknown, and hence we are unable to use a fixed zero point for longitude. Since 1879, however, the great red spot has been used as the reference point, and ephemerides have been published annually by Marth, which have been of great value for the proper reduction of observations.

The great red spot has had a gradual, but not uniform retrograde drift in longitude during the whole interval.

The rotation period of the planet, as given by the red spot, was as follows:

1879	$R = 9^h\ 55^m$	$34^s.2$
1886		39.9
1896		41.4

The spot has also drifted in latitude, the total displacement being $2''.1$ of arc.

The maximum latitude (distance from the equator) was $-7''.41$ in 1886, minimum value $-5''.32$ in 1892.

The shape and size of the spot has, however, remained nearly constant during the whole period of its visibility. It appears to be one of the most permanent features on the disk. The equatorial belt has shifted in latitude, both at the north and south margins. The belt has also changed in width, due to dissipation of the material of which it is composed, or submergence below the surface. The changes are possibly periodic during the Jovian year, due to meteorological causes. The gradual change in the size of the marking, the slow drift in longitude and latitude, show that the surface is in a plastic condition, but its exact nature is as yet unknown. The great permanency exhibited in some of the markings proves conclusively that the phenomenon is not atmospheric, as we use the term, but the medium in which the great red spot and equatorial belt are floating may have a density approximating that of a liquid.

G. W. Hough.

ASTRONOMICAL PHOTOGRAPHY WITH SMALL LENSES.

The photographs exhibited were made with the Willard 6-inch portrait lens during my connection with the Lick Observatory. This lens was 31 inches focus and was originally in the possession of a pho-

tographer in San Francisco, where it had been used in the early days of wet plate work, and was purchased by the Lick Observatory for a small sum. It was refigured by Brashear and in the first work (before refiguring) was strapped to the 6-inch equatorial as a guiding telescope. It was later attached to an ordinary equatorial mounting which did not permit the exposure to be carried over the meridian. A small 2-inch telescope was used to guide by when so mounted. The lens was made by Willard, New York, in 1859.

I had previously attempted to photograph the Milky Way at Nashville and at the Lick, but the lenses were not suited for that purpose. I believed that it could be done if the proper lens could be had. This large portrait lens proved to be the instrument best suited for the work, and the first photographs ever made to show the structure of the Milky Way, were secured with it in July and August of 1889.

This lens was used not only for photographing the Milky Way and the nebulæ, but also for the photography of comets and experimental work on the Earth-lit portion of the new Moon.

Description of the pictures.—Several different views of the crescent Moon were thrown upon the screen, showing the Earth-lit portion of the lunar world. The details on the dark part were clearly shown with less than half a minute's exposure. These pictures showed that the solar rays after having been reflected from the Earth's surface to the Moon and thence back again to the Earth, were sufficiently strong in actinic power to give a clear and distinct picture of the Moon's surface during the lunar night.

It was suggested that a photometric study of such photographs might lead to very interesting results concerning the changing reflective power of the Earth due to the distribution of land and water and clouds as seen from the Moon at different times. It was further found that with a small "lantern lens" 1½ inches in diameter and 5⅓ inches focus, the dark part, when the Moon was a thin crescent, could be readily photographed in one second—thus showing the enormous increase of effective light-grasping power of the smaller lens over the larger one.

A photograph of the total lunar eclipse of 1895, September 3, when the Moon was near the center of the Earth's shadow, showed the Moon and its surface detail clearly and sharply defined. The exposure was seven minutes, which was much longer than necessary to show the details when in the shadow. A number of photographs, up to twenty-three minutes' exposure, were made during the eclipse with the main purpose

of a search for any possible satellite to the Moon, which might at the time be outside the shadow and thus be caught by the sensitive plate, while the light of the Moon itself was dimmed. Nothing was shown that would indicate the existence of a satellite to the Moon as bright as the eleventh or twelfth magnitude.

A photograph of the solar corona at the total eclipse of January 1, 1889, made with a 3½-inch non-photographic telescope reduced to 1¾ inches, showed not only the details close to the Moon's limb, but also the great equatorial extensions of the corona and the beautiful symmetrical polar fans. The exposure was only 3½ seconds. Attention was called to the fact that great care was required in the development of such a picture, to avoid the burning out of the bright details of the inner corona.

Various photographs of different portions of the Milky Way showed the remarkable structure of the galaxy. Particular attention was called to the vacant lanes and black holes and geometrical arrangements of the stars at certain points. Many portions of the Milky Way seemed to consist of thin sheetings of stars with enormous black rifts in them as if these portions were breaking up. The most remarkable of these pictures was one showing the extraordinary appearance of the sky about the great nebula of Rho Ophiuchi. The nebula (which was discovered with the Willard lens) was shown to occupy a great vacancy among the stars, from which sharply defined vacant lanes ran eastward for many degrees. This entire region seemed to be nebulous, and the smaller stars — which seemed to be of a uniform size — appeared to be actually mixed up in this nebulosity. From the fact that the nebulosity was connected also with some of the bright naked-eye stars of this region, there was good reason to believe that the smaller stars here, forming the groundwork of the Milky Way, must be really very small bodies compared with our Sun, for, from their connection with the nebula, they appeared to be at the same distance as the bright stars which were also connected with the same nebula, but which were themselves comparable in size with our own Sun.

Some of the photographs showed vast regions of the Milky Way to be involved in diffused nebulous matter; such as the regions of 15 Monocerotis, in Cepheus, in Cygnus, etc. These pictures gave the impression that the stars at those points were freely mixed up in this nebulosity without any special tendency to individual condensation which is a striking feature of the diffused nebulæ of the sky.

Many photographs of the nebulæ were exhibited—especially the exterior nebulosities of the Pleiades where streams and masses of nebulosity, connected directly with the Pleiades, were shown to exist for many degrees about the cluster.

A picture of the great curved nebula, extending over almost the entire constellation of Orion, showed what wonderful power lay in the small lantern lens for work of this class. The best exposure for this object, with this lens, seemed to be about one hour. The brighter portion of the nebula, near 56 and 60 Orionis had, however, been distinctly shown on a photograph with the Willard lens, with three hours exposure.

An enlarged photograph of the great nebula of Andromeda, showed clearly the ringlike structure of the nebula, and all the features that had been previously photographed.

Photographs of the comets of Swift, Holmes, Brooks, and Gale, showed the remarkable features of these bodies, and the extraordinary changes that utterly transformed them night after night. Brooks' comet of 1893 was perhaps the most remarkable of these bodies. Successive photographs of it showed the tail shattered and broken in a most extraordinary manner. To explain the appearances of the tail, it was suggested that some force outside that existing in the Sun and comet must have produced these malformations. Such distortions would probably be produced by the encounter of the tail with some resisting medium—such as meteor-streams or swarms, which we know exist in space. One of the pictures, which showed the tail bent abruptly at right angles, near its end, could only be explained by supposing some external force of this kind.

Among these pictures was one of the discovery of comet V 1892. A fuzzy trail was found on developing a star plate on October 12, 1892. This was suspected to be due to a comet, which was actually found upon searching for it in the sky. This comet was subsequently observed at the principal observatories of the world, and was found to be moving in an ellipse with a period of about six years. The picture is unique, as it contains the only actual discovery of a comet by photography.

A photograph of Brooks' comet on the morning of November 14, 1893, showed a fine meteor trail crossing the plate near the comet. The beginning of the trail—where the meteor first struck the atmosphere—is shown, but it passed off the plate before exploding. Three

other meteor photographs were exhibited — one of a stationary meteor. The other two pictures were of the same meteor with two different cameras, and were obtained at the Yerkes' Observatory, August 10, 1897.

The paper was concluded by the exhibition of a number of photographs of the Milky Way made with the small "lantern lens." These showed what extraordinary results could be obtained with such modest means — where the lens cost only a few dollars.

It was found that this small instrument would readily photograph in ten or fifteen minutes what it took the Willard lens from three to four hours to show. It had proved specially fine for photographing such diffused nebulosities as that connected with the great nebula of Rho Ophiuchi, which was shown by it to extend some degrees west of Antares. With this small lens the great wing-like nebula about Nu Scorpii was discovered. A sufficient number of photographs had been made with it to partially construct a map of the Milky Way, which, while showing vastly more than the eye could see, would more nearly resemble the naked eye view of the galaxy.

E. E. BARNARD.

RESEARCHES ON PLANET 334, CHICAGO.[1]

Planet 344 was discovered by Professor Wolf of Heidelberg, by the photographic method on August 23, 1892.[2] From two photographic observations of August 23 and 29, Mr. Berberich derived a circular orbit with a mean daily motion of 460″. At the time of the discovery the magnitude of the planet was the twelfth. Dr. Palisa of Vienna succeeded in finding the planet with the equatorial of twenty-seven inches on November 22, and up to December 8 of the same year secured altogether four observations. Two more observations were obtained from Professor Wolf's photographic plates in the months of October and November. Uniting all of these observations Mr. Berberich has derived a first set of elliptical elements which he has published in *A. N.*, 3202. In this note Mr. Berberich calls attention to the large perturbations which this planet undergoes from Jupiter. He obtains for 1893, November 16, the following perturbations of the elements:

$$\delta M + 30^\circ\ 38'\ 50''.8 \qquad \delta i - 0^\circ\ 0'\ 41''.4$$
$$\delta\omega - 30^\circ\ 38'\ 9''.9 \qquad \delta\phi - 0^\circ\ 18'\ 2''.3$$
$$\delta\Omega - 0^\circ\ 18'\ 59''.7 \qquad \delta\mu - 4''.115$$

[1] Provisional Report.

[2] At the astronomical conferences at Chicago, August 1893, Professor Wolf gave to the planet the name "Chicago," in memory of the World's Fair event.

Indeed the distance 334 — Jupiter becomes quite small, so small that in 1894 it decreased to 1.25 units, the radius vector of 334 being 3.90 units. The perturbing force of Jupiter compared with the attractive force $= \frac{1}{1047}\left(\frac{3.90}{1.25}\right)^2 = \frac{1}{108}$.

In the case of Saturn the same fraction is but $\frac{1}{250}$. During the next opposition the only observations obtained are those of Dr. Palisa on December 3, 4, 31, and January 2, 1894. Mr. Berberich has united all of the observations between 1892 and 1894 and arrives at the following set of elements:

Epoch, November 16, 1893, M. T. Berlin.

$$\begin{array}{llll} M & 278^\circ\ 45'\ 55''.1 & & \\ \omega & 347^\circ\ 34'\ 11''.3 & \multirow{4}{*}{$\left.\begin{array}{l}\\ \\ \\ \\ \end{array}\right\}$ 1900.0} & \\ \Omega & 135^\circ\ 50'\ \ 3''.3 & & \\ i & \ \ 4^\circ\ 33'\ 26''.9 & & \\ \phi & \ \ 0^\circ\ 25'\ 14''.5 & & \end{array}$$

μ 456''.3980

log a 0''.593775

In 1897 the planet has been observed at the Algiers Observatory and seven observations were secured. (*Bull. Astr.*, September 1897, p. 360.) Professor James Hart, of Maine State College, has examined[1] the perturbations of Jupiter on the planet between November 16, 1893, and May 10, 1895, by the method of special perturbations. He has found a perturbation in $\mu, \Delta\mu = -2''.841$, $\Delta\phi = -13'\ 24''.6$. The planet, therefore, very closely approaches the case where $\mu = 450''$ is fulfilled. On this account long period inequalities will become very sensible, and the planet deserves special attention first, since it comes so near to Jupiter, and second, since the mean motions of the two are nearly commensurable. The perturbing action of Jupiter will decrease the eccentricity until it becomes zero; an increase to negative values will mean a change of the perihelion by 180°. The value of $\Delta\omega = -69^\circ\ 31'$, which Mr. Hart has found is not well enough determined and can be regarded only as an approximation. This is due to the method employed. The variation of the elements, especially those of ω and M, are so considerable that new elements should be derived after every period of forty days. This has not been done, but the same set has been retained during a year and a half. Mr. Hart's work had advanced too far before I noticed the desirability of such a change; we must therefore regard his results, so far as ω and M are concerned, as approximate only.

[1] In a thesis for M. S. at the University of Chicago.

Mr. Moulton and I have recently attempted to derive general tables for planet 334. Leverrier's method of absolute perturbations has been used, since the small eccentricity and the small inclination of the planet seemed to recommend this method in the first place. The great advantage which the smallness of e and $\eta = tg\frac{I}{2}$ presents, is somewhat counterbalanced by the greatness of the value of $\alpha = \frac{a}{a'}$, which amounts in this case to 0.7543. The coefficients of the development depend upon the expansion of $(1 + \alpha - 2\alpha \cos w)^{-s} = \frac{1}{2}\Sigma L_s^{(i)} \cos iw$, where s assumes the values $\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$. In the second volume of the *Annales de l'Observatoire de Paris*, Leverrier gives the general expressions for the L_s^i quantities from $i = 0$ to $i = 15$. This limit is not exceeded in any of the larger planets, since only in the case of Venus and the Earth does α amount to 0.723, and here the mass of the perturbing planet is less than $\frac{1}{300}$ of the mass of the perturbing planet in the present case. When neglecting in the perturbations of the elements quantities $< 0''.1$ we have to go in the absolute terms to $i = 25$. The last quantity in the periodic terms will therefore be of the nature $h \cos 25 (l' - \lambda)$. Since the coefficients are small and decrease uniformly, the additional work is not very heavy, since an extrapolation will give sufficiently accurate results in the last values. We have completed the determination of the secular perturbations including the third power of small quantities. In the periodic terms the perturbations including the second powers are nearly finished. The extension of this work from $i = 15$ to 25 is not yet done. Nor have we yet ascertained to which power of small quantities the work will have to be pushed in order to keep inside of the above mentioned limit. From the tenth volume of the *Annales* those terms have been gathered which will introduce long period inequalities; they have been extended to small quantities of the fourth order. Whereas the long period inequality of Jupiter and Saturn does not occur multiplied with the first or second power of small quantities, we find in this case, terms multiplied with the first power. Indeed, the argument of the trigonometric functions which are multiplied with the factors $\frac{1}{i\nu' + i,}$ where $\nu = \frac{n'}{n}$, are $3l' - 2\lambda$ or multiples of this angle. To retain all values $> 0''.1$ in the perturbations of the elements it will probably be necessary to include the principal terms of the second

order of the mass of Jupiter and to investigate also the most important terms of the perturbing influence of Mars and Saturn.

KURT LAVES.

RESEARCHES IN SOLAR PHYSICS.

Professor Hale exhibited a number of lantern slides illustrating his solar investigations.

A PHOTOGRAPHIC MERIDIAN CIRCLE.

By F. L. O. Wadsworth. (To be published in the *Monthly Notices of the Royal Astronomical Society.*)

The following papers were presented but could not be read for lack of time.

THE WORK OF THE CATANIA ASTROPHYSICAL OBSERVATORY.[1]

The following establishments are comprised in the Observatory of Catania:

(1) Astrophysical, photographic, meteorological and seismological Observatory in the city of Catania.

(2) Astrophysical, meteorological, and seismological Observatory near the summit of Mount Etna (2950^m).

(3) Meteorological station on the south slope of Etna (1900^m).

(4) Network of thirty seismological stations in Sicily and the neighboring islands.

With a few exceptions, the various buildings and laboratories have been built and equipped under the supervision of the Director, Professor A. Riccò.

The work of the Observatory has been as follows:

1891.—Restoration of the Mount Etna Observatory after its damage by the volcano. Preparation of rooms for meteorological instruments in the upper story of the Catania Observatory, and for seismological instruments in subterranean vaults. Mounting of the $5^m.50$ refractor in Catania and on Mount Etna. Investigations of the eruption of Stromboli and of the submarine eruption near Pantelleria.

1892.—Beginning of daily observations and drawings of solar spots and prominences. Beginning of meteorological and seismologi-

[1] A series of photographs of the buildings and instruments of the Catania Observatory was placed on exhibition during the conferences.

cal observations. Mounting of the photographic equatorial. Observations and drawings of planets at Catania and on Mount Etna. Studies of the great eruption of Etna.

1893.—Mounting of the 6-inch Cooke equatorial, and the transit instrument. Beginning of astronomical photography. Attempts to photograph the solar corona in Catania and on Mount Etna. Drawings of planets in Catania and on Mount Etna. Observations of the solar eclipse of April 23. Observations of telluric lines at Catania (50^m), Nicolosi (700^m) and Mount Etna (2950^m). Studies of Etnean earthquakes and partial eruption.

1894.—Modification of the photographic equatorial. Determination of the latitude and longitude of the Catania and Mount Etna Observatories. Attempts to photograph the solar corona in Catania and on Mount Etna with Huggin's and Hale's apparatus. Photographs of the rising Sun and of clouds. Actinometric observations in Catania and on Mount Etna. Studies of the Calabrian earthquakes.

1895.—Modification of the photographic equatorial. Drawings of planets. Mounting of a great seismograph (pendulum 25^m long, weighing 300^{kg}). Geophysical studies of the Æolian Islands and of the Val di Noto earthquake.

1896.—Beginning made in photographing the stars of the Catania zone ($43°$), previous plates having been made for the catalogue. Drawings of planets. Cartographic studies.

1897.—Mounting of photographic spectroscope. Observations of eclipses of Jupiter's satellites. Photographs of the Milky Way with a Voightländer portrait lens. Simultaneous meteorological observations on Mount Etna (1900^m station), at Nicolosi, at Catania, and on the seashore.

The solar observations are published in full in the *Memorie degli Spettroscopisti Italiani*, the observations of planets in the *Astronomische Nachrichten*, and the meteorological and seismological studies in the *Annali dell' Ufficio Centrale Meteorologico e Geodinamico di Roma*. The principal results of our work are given in the *Rendiconti della R. Accademia dei Lincei*, the *Bulletino dell' Accademia Gioenia* in Catania, or the ASTROPHYSICAL JOURNAL.

The staff of the Observatory is as follows:

Director,	Professor A. Riccò
First Assistant,	Eng. A. Mascari
Second Assistant,	Professor G. Saija

Third Assistant, - - - - - - - - -	Dr. E. Tringali
Mechanician, - - - - - - - - - - -	A. Capra
First Guardian of the Etna Observatory, - -	A. Galvagno
Second Guardian of the Etna Observatory, - -	A. Messina

Three servants and two mechanician's apprentices.

A. Riccò.

ON THE ANALYSIS OF ELECTRIC RADIATION.

In attempting to analyze electric radiation by means of the two principles used in light we must bear in mind (1) that in general we need not expect dispersion of electric rays by ordinary matter, (2) that the receiver usually influences the measured wave-length and consequently affects, apparently, the radiation. Using the principle of dispersion Garbasso and Aschkinass found, by means of a prism of glass plates upon which were pasted strips of tinfoil, that the electric radiation was dispersed and concluded that rays of electric force may be considered, not necessarily as monochromatic, but, with the same justification as in the case of light, as composite. Using the principle of interference Sarasin and de la Rive found that the wave-length measured depends on the receiver, and Zehnder that rays of electric force are analyzed by a grating into a spectrum. Both results point to a complexity of electric radiation, but Bjerknes and Poincaré point out that they may be explained on the assumption that the radiation is simple and damped.

The author used an interferometer and nail receiver to analyze the radiation from spheres. The interference curve was approximately a damped cosine curve. In interpreting this curve, if the influence of the receiver on it be not considered, the conclusion is reached that the radiation is a damped sine function of the time. But it was found, using different receivers, that the form of the curve was influenced by the receiver and therefore that the latter possessed a definite period and was not dead beat. The problem is thus more complicated than the corresponding one of light. Using a number of receivers a fair approximation regarding the nature of radiation from spheres may be arrived at and the conclusion is drawn that it is less highly damped than theory leads us to believe and that it is practically simple.

G. F. Hull.

THE PSYCHOLOGY OF THE PERSONAL EQUATION.

By Truman Henry Safford (see *Science*, November 26, 1897).

ON THE VARIATION OF SOLAR RADIATION.

By Frank W. Very (to be published in the ASTROPHYSICAL JOURNAL).

ON THE ROTATION OF THE SUN.

By L. E. Jewell.

OXYGEN IN THE SUN.

IN a note published in the ASTROPHYSICAL JOURNAL for February 1897, I gave the results of some observations made upon three lines in the solar spectrum at λ 7772.20, 7774.43 and 7775.62 which were thought by Runge and Paschen to belong to the spectrum of oxygen and also to be true solar lines.

As the result of several comparisons made between these lines and lines of the A group (due to atmospheric oxygen), on December 24, 25, 27 and 31, 1896, and on January 4, 1897, I announced that the evidence given by these comparisons seemed to be conclusive that the lines in question were of atmospheric origin, but were not due to atmospheric oxygen and were probably due to water-vapor.

A continuation of comparisons as the Sun's altitude became higher in the spring, together with the use of better absorbing media to render the extreme red end of the spectrum more easily visible, and improved methods of comparison, showed that altogether too much confidence had been placed in the early comparisons; and later the accumulating evidence indicated that the earlier observations were quite unworthy of the confidence placed in them, and that the lines in question were probably solar lines, and certainly did not vary in intensity in the same manner as the known lines of water-vapor.

The methods of comparison used were rendered necessary by the difficulties of observing in the infra-red, difficulties caused not alone by the exceeding faintness of the solar spectrum in this region, but by the very rapid change in the intensity of the spectrum at and beyond the A group. Another cause of difficulty, and probably the cause of much of the error in the earlier observations, is the overlapping ultra-violet spectrum and the presence of much diffuse light.

It was necessary to confine observations to the first spectrum because of the lack of sufficient light in the second, but nevertheless the dispersion used was very considerable. A pretty dense red glass was used, but this alone let through so much diffuse light of a red and orange

color that the spectrum in the infra-red could not be seen much beyond the A group, and not well there. Consequently a fairly dense cobalt blue glass was used, which rendered observation possible, although considerable ultra-violet light was visible, which greatly weakened the apparent intensity of lines having greater wave length than about λ 7700 while not materially affecting the lines of the A group.

Later on it was found that a combination of cobalt blue and orange glass gave very much better results, and this was used except for the earlier observations. Still later it was found that a cobalt blue glass, used with a glass cell containing a solution of potassium bichromate or potassium chromate, gives excellent results, though another cell filled with some of the aniline dyes will probably be an improvement upon the blue glass.

The line at λ 7699.1 being the only solar line in the neighborhood of whose character I was at all confident, comparisons were mostly confined to this line and the lines of the A group.

These lines were all at some distance from the lines with which the comparisons were made, thus rendering the comparisons difficult as well as somewhat uncertain; particularly upon days when the infra-red spectrum was weak or when the overlapping ultra-violet was exceptionally strong. But it was the only method available under the circumstances.

Considerable reliance was at first placed upon the circumstance that although the three lines forming the triplet observed were difficult to see near noon, yet they were scarcely more difficult to see near sunset. On some days they were certainly rather more prominent at this time, and on particularly clear days late last December were seen when the Sun was within a degree or two of the horizon.

It is now evident that this apparent increase in intensity was due to the effect of the overlapping ultra-violet light in diminishing the apparent blackness or intensity of the lines in the infra-red at the noon observations. This must have been particularly true upon clear cold days, while the atmospheric absoption of ultra-violet light would render these lines more distinct with the Sun at a less altitude. This is probably also the reason why these lines seemed to be considerably stronger upon the warm moist days of December 31 and January 4.

After the orange glass was used these differences ceased to be observed, or at least were not so evident.

The observing method used was to compare the intensity of the

lines under consideration with the lines in the A group, which were most nearly of the same intensity. Some comparisons were also made with the solar line at 7699.1, but they were not satisfactory. However, indirect comparisons were satisfactorily made by comparing this line with the lines of the A group at different altitudes of the Sun.

These observations have been reduced, and though they are not particularly accurate individually, and not always as consistent as could be desired, yet the means of the observations, at different altitudes of the Sun, conform fairly well to a curve which represents the change in the relative intensity of a solar line when compared with the lines of the A group. The change in intensity of these lines with change in the altitude of the Sun is readily determined from the results of observations made during 1892 and 1893.[1]

Attempts have been made upon various occasions to test the solar origin of these lines by observing their positions at the east and west limbs of the Sun, but the seeing has never been good enough to make satisfactory settings of the cross hairs when the edge of the Sun was upon the slit. Several attempts have also been made to determine whether the lines were affected over a Sun-spot or not. But I could never detect any difference between their behavior and that of lines of the A group (which are due to atmospheric oxygen). The seeing was never sufficiently good in the extreme infra-red to permit the detection of any slight differences, if any existed.

In a recent paper in *Wiedemann's Annalen*, Professor Runge gives the wave-lengths and relative intensities of numerous lines of oxygen, two triplets of which he considers to be present in the solar spectrum.

I have recently carefully examined the lines in the beginning of the ultra-violet which he has assigned to oxygen. The lines are of true solar origin and the coincidence and relative intensities in the solar and oxygen spectrum agree fairly well for the lines 3947.50 and 3947.78.

If the wave-lengths of the oxygen lines given be not considered very exact and the first and last lines of the triplet be considered to be the same as the solar lines, then the middle line could be placed at the red edge of the solar line at 3947.675, when the appearance of the triplet would be quite similar to the one in the infra-red.

The solar line at 3947.675 (which is due to iron) shows, however, no signs of duplicity or shading at the red edge.

[1] This JOURNAL, 5, 324.

The other two solar lines are considerably weakened and somewhat broadened at the Sun's limb, an indication that the origin of the lines is at a considerable depth in the solar atmosphere. There is no difference between the appearance of these lines and that of the smallest metallic lines.

LEWIS E. JEWELL.

LARGE MAGELLANIC CLOUD.[1]

STARS whose spectra are of the fifth type consisting mainly of bright lines have hitherto been found only near the central line of the Milky Way. Of the 67 stars of this type so far discovered the average deviation from this line is $2° 39'$. For only one object, whose distance is $17° 39'$, does the deviation exceed $9°$. It is difficult to explain this very close approach to a great circle, as these stars fall in a band much narrower than the Milky Way itself. This law of distribution is one of the most important results attained by means of the Henry Draper Memorial. The two Magellanic Clouds closely resemble the Milky Way in appearance, although completely detached from it, and distant from its central line by about $33°$ and $45°$ respectively. From an examination of the photographs of the spectra of the stars in the large Magellanic Cloud, recently taken with the Bruce photographic telescope, Mrs. Fleming has discovered six stars whose spectra are of the fifth type; also that bright hydrogen lines are present in the spectra of seven stars of the first type, and that the spectra of six known nebulæ are gaseous and not continuous. The power of the instrument and the quality of the photographs are shown by the fact that, with one exception, all of these stars are so faint that they have not been included in any of the star catalogues as yet published. A list of these objects is given in the following table. The successive columns contain the approximate right ascensions and declinations for 1900, the galactic longitudes and latitudes of the nebulæ and stars of the fifth type, and a brief description of the objects.

The fifth star is variable and has a range of rather more than one magnitude. It is identical with Gilliss No. 3092.

The tenth object is identical with the second object, announced as a gaseous nebula, in *Circular* No. 17. Small gaseous nebulæ and faint fifth type stars can be distinguished photographically only by the wavelength of the principal line in their spectra. Accordingly, on the

[1] *Harvard College Observatory Circular* No. 19.

R. A. 1900	Dec. 1900	Gal. long.	Gal. lat.	Description
h m				
4 54.6	−69° 21′	247° 14′	−35° 16′	Gaseous nebula. *N. G. C.* 1743.
4 56.4	−66 37	243 54	−35 44	Type V. Brightest star in *N. G. C.* 1761.
4 56.5	−66 34	243 51	−35 44	Gaseous nebula. *N. G. C.* 1763.
5 14.0	−67 34	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. In *N. G. C.* 1871.
5 18.9	−69 21	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. Variable. In *N. G. C.* 1910.
5 20.1	−69 45	247 10	−33 1	Type V. In *N. G. C.* 1918.
5 25.6	−68 33	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. In *N. G. C.* 1849.
5 30.4	−67 30	244 24	−32 20	Type V.
5 32.0	−71 6	248 37	−31 51	Type V.
5 35.2	−69 49	247 5	−31 43	Type V.
5 35.6	−67 39	244 32	−31 50	Gaseous nebula. *N. G. C.* 2029.
5 37.2	−69 26	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. In *N. G. C.* 2050.
5 39.3	−69 8	246 15	−31 24	Gaseous nebula. *N. G. C.* 2070. 30 Doradus.
5 39.5	−69 5	246 11	−31 23	Type V.
5 40.6	−69 49	247 2	−31 15	Gaseous nebula. *N. G. C.* 2079.
5 40.6	−69 42	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. In *N. G. C.* 2080.
5 40.6	−69 42	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. In *N. G. C.* 2080.
5 40.7	−69 27	246 37	−31 16	Gaseous nebula. In *N. G. C.* 2081.
5 41.0	−69 26	... ..	....	Type I. $H\beta$, $H\gamma$, and $H\delta$ bright. In *N. G. C.* 2081.

Bache plates the bright line was assumed to be due to a gaseous nebula and was identified with a faint adjacent star. Two Bruce plates show that the spectrum is that of a fifth type star following $0^m.1$, north $3'$.

The gaseous character of the nebulosity surrounding 30 Doradus is well known. These photographs show that several objects closely adjacent to it have bright lines in their spectra.

After the above description had been prepared a letter was received from Peru, from which it appeared that the presence of bright lines in the spectra of several of these stars had already been found by Dr. Stewart at Arequipa. His description of each object is given below preceded by its right ascension :

R. A. 4^h $54^m.6$. Four bright lines including $H\beta$, $H\gamma$, and $H\delta$.
R. A. 5^h $14^m.0$. $H\beta$ and $H\gamma$ bright.
R. A. 5^h $18^m.9$. $H\beta$, $H\gamma$, and $H\delta$ bright.
R. A. 5^h $20^m.1$. $H\beta$ bright and broad.

R. A. $5^h\ 25^m.6$. *Hβ* somewhat bright, not intense.

R. A. $5^h\ 32^m.0$. *Hβ* somewhat bright, broad, not intense.

R. A. $5^h\ 35^m.2$, *Hβ* bright and broad, partial spectrum only visible.

R. A. $5^h\ 37^m.2$. *Hβ*, *Hγ*, and *Hδ* bright.

R. A. $5^h\ 39^m.3$. *Hβ* and *Hδ* bright.

R. A. $5^h\ 40^m.6$ (first). *Hβ* bright and broad.

R. A. $5^h\ 40^m.6$ (second or third). *Hβ*, *Hγ*, and *Hδ* bright and broad.

R. A. $5^h\ 41^m.0$. *Hβ*, *Hγ*, and *Hδ* bright and sharp.

The line called *Hβ* by Dr. Stewart in the first, ninth, and tenth of these objects is probably the line 5007, characteristic of gaseous nebulæ. The line called *Hβ* in the fourth, sixth, and seventh objects is probably the line 4688, characteristic of spectra of the fifth type.

September 28, 1897. EDWARD C. PICKERING.

SPECTRUM OF A METEOR.[1]

THE photographs of the spectra of the stars taken at the Harvard College Observatory as part of the Henry Draper Memorial differ in two respects from those ordinarily taken elsewhere. Instead of using a spectroscope with a slit, in which but one star is photographed at a time, a large prism is placed over the object-glass of the telescope and thus spectra of all the bright stars in the field of view are obtained. The number of stars photographed simultaneously is still further increased by substituting for the object glass a portrait lens like that used by photographers, only larger. The field of view is in this way increased from two degrees squàre to ten degrees square, and a photograph is obtained of the spectra of all the brighter stars in this large region. Many thousand plates covering the entire sky, have been taken in this way at the Cambridge and Arequipa Stations of this Observatory. All have been examined by Mrs. Fleming and, as a result, numerous remarkable objects have been discovered. One of the latest is the spectrum of a meteor which has thus been photographed for the first time. Since it is impossible to foresee when the bright meteors will appear, or what path they will follow, a photograph will be obtained only when one happens to cross the field of the telescope. A number of trails of meteors have been obtained, both here and elsewhere, when charts of the stars were photographed, no prism being

[1] *Harvard College Observatory Circular* No. 20.

used. When the prism was in place no meteor bright enough to leave a noticeable trail has heretofore been photographed on the many thousand plates examined. At about 11:00 P.M. on June 18, 1897, however, when the 8-inch Bache telescope at Arequipa was directed toward the constellation Telescopium, a bright meteor appeared in right ascension $18^h\ 19^m$, declination $-47°\ 10'$, and passed out of the field at right ascension $18^h\ 29^m$, declination $-50°\ 30'$. The spectrum consists of six bright lines whose intensity varies in different portions of the photograph, thereby showing that the light of the meteor changed as its image passed across the plate. The approximate wave-lengths of these lines are 3954, 4121, 4195, 4344, 4636, and 4857, and their intensities are estimated as 40, 100, 2, 13, 10, and 10, respectively. The first, second, fourth, and sixth of these lines are probably identical with the hydrogen lines $H\epsilon$, $H\delta$, $H\gamma$, and $H\beta$, whose wave-lengths are 3970, 4101, 4341, and 4862. The fifth line is probably identical with the band at wave-length 4633, present in spectra of stars of the fifth type and forming the distinctive feature of the third class of these stars. The third line, which is barely visible, is perhaps identical with the band at wave-length 4200, contained in these stars. (*A. N.* **127**, 1).

It will be noticed that of the four hydrogen lines in the spectrum of the meteor, $H\delta$ is the most intense. This is also the case in the spectrum of *o* Ceti and of many other variable stars of long period. In some variables of long period $H\delta$ and $H\gamma$ are equally intense, while in others $H\gamma$ is the more intense. In some stars of the first type in which the hydrogen lines are bright, like γ Cassiopeiae, the line $H\beta$ is much more intense in the photographic spectrum than any of the other lines, while in the spectra of stars like P Cygni and η Carinae, $H\delta$, $H\gamma$ and $H\beta$ are nearly equally bright. These results show an important resemblance between meteors and stars having bright lines in their spectra, and may aid in determining the conditions of temperature and pressure in these bodies. Since bright meteors sometimes appear during the November meteoric shower a special effort will be made here to obtain photographs of them, both trails and spectra, on November 13.

November 8, 1897. EDWARD C. PICKERING.

LOSS OF LIBRARY BY FIRE.

ON September 14, 1897, at 1:30 A.M., the Grand Canyon Hotel in Flagstaff was discovered to be on fire, and within twenty minutes from

the first alarm the entire building was in flames. Owing to the headway already made before the alarm was given, and the insufficiency of the water supply, and the consequent weakness of the fire department, all hope of saving the contents of the building was at once given up. In this hotel had been the office of Mr. Cogshall and myself ever since the beginning of our work with the Lowell Observatory, August 1, 1896; and our apartments contained all the mathematical, astronomical, physical and other books which I had brought with me from Chicago, or since purchased; besides various precious papers, letters, manuscripts, pictures, etc., and the records of our work on the double stars of the southern hemisphere. The night being unfavorable for observations we had retired; and in the hurried moments of darkness and confusion attending the evacuation of the burning building, we were barely able to save the records of the Observatory, the general manuscript catalogue of all double stars within 75° of the south pole, and a few other works such as the *Mecanique Celeste*—everything else, the library of books, the manuscripts, letters, pictures, personal effects being a total loss.

As this destruction of the library will necessitate the formation of a new one, I beg to state that I am desirous of restoring first the astronomical works relating to the double stars of the southern hemisphere. If friends or other men of science with whom I have exchanged publications should have copies or reprints of their works which they would feel disposed to offer, I need hardly add that they would prove very useful and be received with grateful appreciation.

T. J. J. SEE.

LOWELL OBSERVATORY,
Flagstaff, Arizona, September 16, 1897.

A NOTE ON THE THEORY OF TELESCOPIC IMAGES.

I HAVE just discovered an important error in the result, for the focal plane illumination due to an infinitely extended source, which was first obtained by LORD RAYLEIGH and STRUVE, and which has recently been used by the writer in developing the theory of the contrasting or delineating power of telescope objectives. This error does not affect, to any degree, the conclusions reached, so far as *practical photographic contrast* is concerned. A paper containing full details will appear in the next number of the JOURNAL.

F. L. O. WADSWORTH.

YERKES OBSERVATORY,
December 16, 1897.

NOTICE.

The scope of the ASTROPHYSICAL JOURNAL includes all investigations of radiant energy, whether conducted in the observatory or in the laboratory. The subjects to which special attention will be given are photographic and visual observations of the heavenly bodies (other than those pertaining to "astronomy of position"); spectroscopic, photometric, bolometric and radiometric work of all kinds; descriptions of instruments and apparatus used in such investigations; and theoretical papers bearing on any of these subjects.

In the department of *Minor Contributions and Notes* subjects may be discussed which belong to other closely related fields of investigation.

It is intended to publish in each number a bibliography of astrophysics, in which will be found the titles of recently published astrophysical and spectroscopic papers. In order that this list may be as complete as possible, and that current work in astrophysics may receive appropriate notice in other departments of the JOURNAL, authors are requested to send copies of all papers on these and closely allied subjects to both Editors.

Articles written in any language will be accepted for publication, but unless a wish to the contrary is expressed by the author, they will be translated into English. Tables of wave-lengths will be printed with the short wave-lengths at the top, and maps of spectra with the red end on the right, unless the author requests that the reverse procedure be followed. If a request is sent *with the manuscript* one hundred reprint copies of each paper, bound in covers, will be furnished free of charge to the author. Additional copies may be obtained at cost price. No reprints can be sent unless a request for them is received before the JOURNAL goes to press.

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All papers for publication and correspondence relating to contributions and exchanges should be addressed to *George E. Hale, Yerkes Observatory, Williams Bay, Wisconsin, U. S. A.*

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SUBJECTS.

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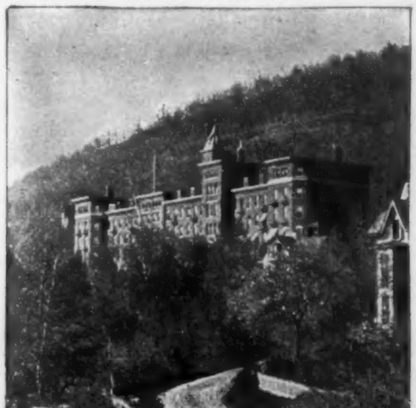

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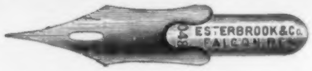

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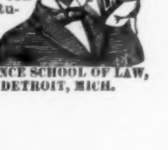

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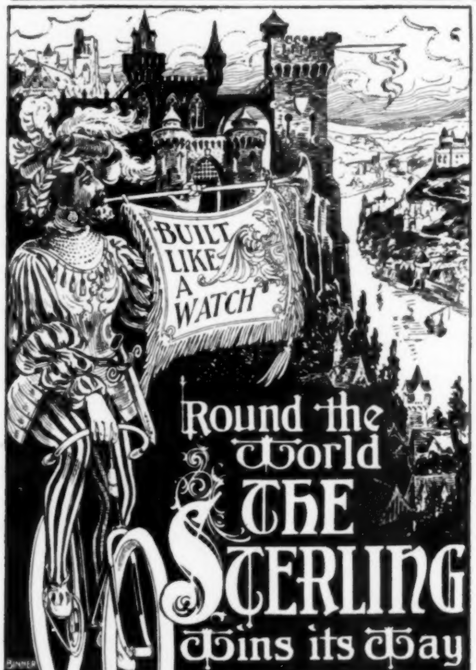

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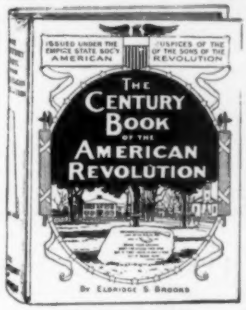

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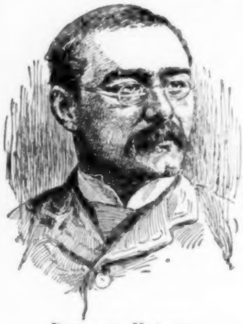

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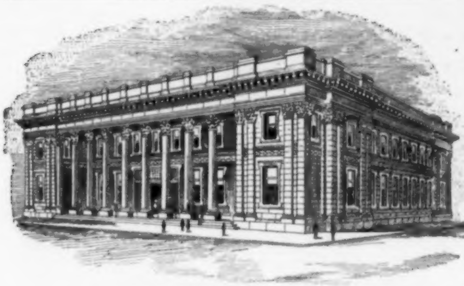

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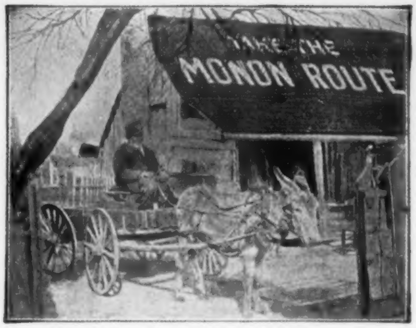

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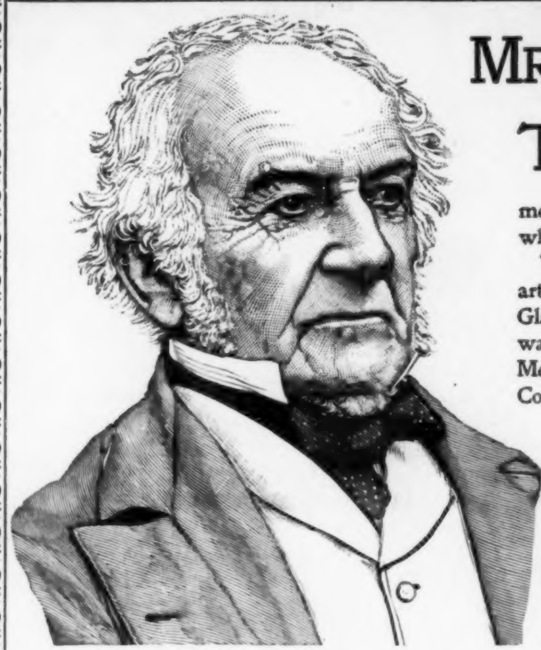

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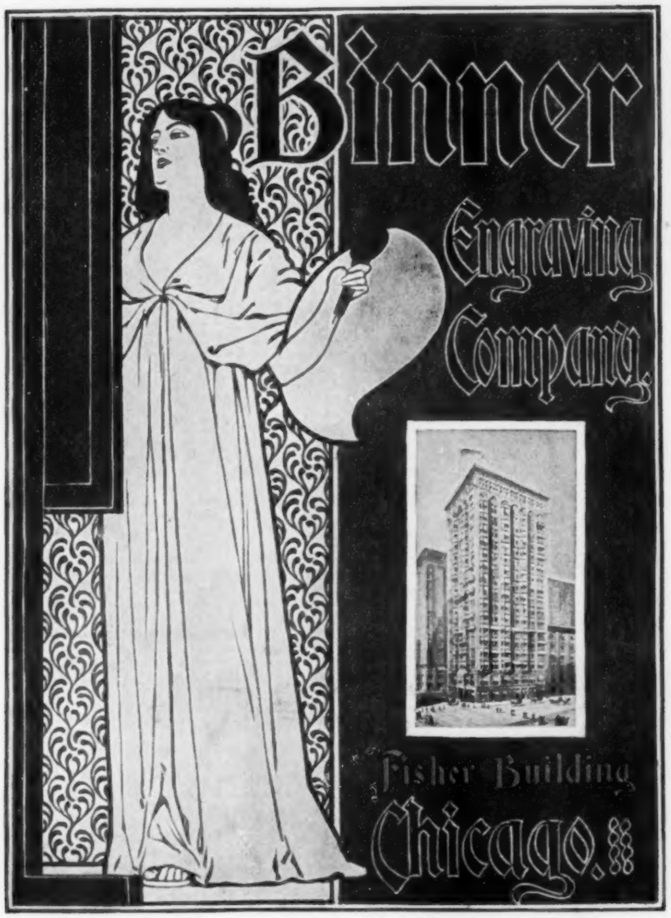

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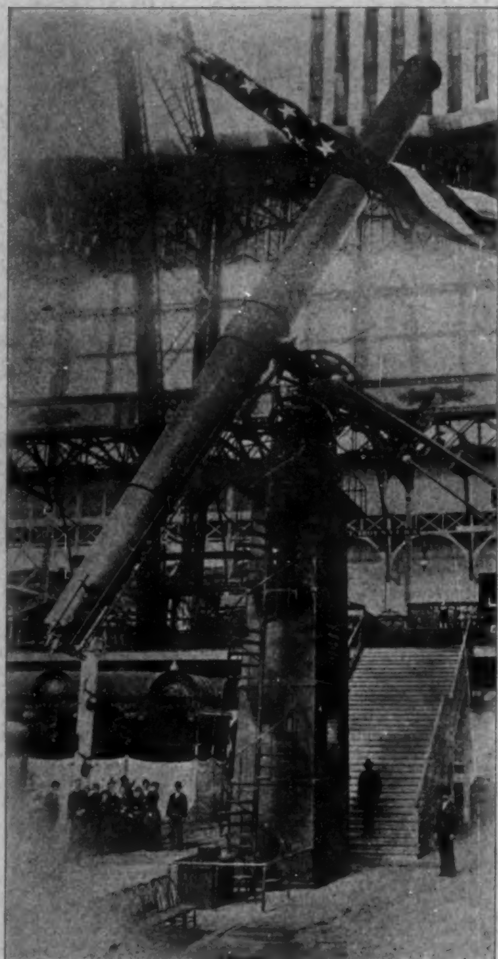

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